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Brit. J. industr. Med., 1947, **4**, 77.

SOME ANATOMICAL PROBLEMS IN NAVAL WARFARE

BY

G. WEDDELL and H. D. DARCUS

From the Department of Human Anatomy, University of Oxford

(RECEIVED FOR PUBLICATION, JULY 23, 1946)

In general, our problems have been concerned with the determination of conditions of work which allow personnel to perform certain routine operations (such as the loading of a heavy gun) precisely, rapidly, and with the minimum of fatigue and discomfort. Having established these conditions by experiment, the results are then applied to the design of machines or weapons as far as mechanical requirements and considerations of limitation of space and weight permit. This procedure leads to a greater efficiency in operation and to a greater economy in manufacture than the usual method, in which the machine receives first consideration and the operator is left to fit himself to the machine as best he can. Owing to improvements in electrical, hydraulic and mechanical design, and to the increased working speed attainable, the weakest link in the operation of any machine is now 'the man behind it.' It is for this reason that so much more attention is being paid to the human factors in engineering design.

Our work for the Navy has included the design of hand and foot controls which may be used in the operation of guns and directors; the design of seats for directors; the design of air look-out sights and moving eyepiece range finders; the design of an emergency power unit using human energy, for the operation of hydraulic light-powered mountings; investigations into the alleviation of vertical thrust injuries due to underwater blast and to vibration in motor torpedo boats; the effects of clothing on the efficiency of operation; the effect of cordite on the efficiency of magazine personnel; and the determination and analysis of composite joint movements, such as those occurring in the spine. In this communication it is not possible to deal with all these aspects of our work. However, two examples have been selected which illustrate the application of the principles we have employed and the results we have obtained; they are the design of a seat capable of fitting all subjects with the minimum of adjustment, and the construction of a high-angle sight, pivoted so that the binoculars can be followed by the eyes with relative ease and without undue straining.

Seats

Seating is a problem which hitherto has received very little attention. This was especially the case in the Navy, for in this Service it is traditional to stand when on duty. However, mainly on account of the increasing menace from air attack in modern naval warfare, it has become imperative to be prepared for immediate offensive and defensive action at all times. This often necessitates watches being at 'action stations' for many hours. To perform such duties while standing incurs an unnecessary expenditure of energy, which leads to an early onset of fatigue with a consequent decrease of efficiency in operating precision apparatus. Thus the provision of adjustable seats designed to minimize discomfort and to allow efficient operation of machines becomes an important matter.

Desiderata

The chief requirements of an 'ideal' seat for use in naval operations are: (1) the accommodation of individuals of different body dimensions within the 90 per cent. (minimum acceptable) range; (2) the ability to attain the maximum degree of body stabilization; (3) the elimination of fatigue; and (4) freedom from breakdown.

1. *Accommodation of personnel.*—The seat must accommodate 90 per cent. of all naval personnel without the operator fouling surrounding structures, but at the same time it must occupy the least possible space. A simple single adjustment of seat height must be provided, so that persons of different stature can fit themselves accurately and rapidly to the seat. The adjustment of seat level must be related to the foot-rest, to allow for varying leg lengths, and also to the oculars of the sight, to allow for varying eye levels.

2. *Body stabilization.*—A method of body stabilization is essential in order to counteract the movements of the ship, gun, or director while observations are being made and operations carried out,

thus making it possible to increase the accuracy of aim, and to prevent 'throw off.' Whatever method is adopted the arms must be left free to manipulate controls, and the mobility of the spine must not be limited. Stabilization by the use of a retaining mechanism is undesirable, for it is liable to restrict the movements of the arms and trunk, and also it unnecessarily increases the manipulations to be performed by the operator, who may have to take up his position in the dark; it adds to the complexity of the equipment, and the adjustment of the harness takes time. Furthermore, the feeling that the harness, even though it may be fitted with a quick-release catch, may hinder rapid escape, has an undesirable psychological effect on the ratings. Body stabilization should be effected by the operator himself with the minimum of muscular effort by counter-pressure between a foot-rest and a back-rest.

3. *Elimination of fatigue*.—To reduce fatigue to a minimum the seat must provide an efficient, comfortable support to the body over prolonged periods. In order to realize this ideal, the design of (*a*) the seat cushion, (*b*) the foot-rest, and (*c*) the back-rest must all be considered.

(*a*) The seat cushion must be wide enough to accommodate subjects of maximum dimensions wearing thick winter clothing, and must allow a certain amount of lateral movement. Its depth must be sufficient to afford light support to the thighs. The thighs must not press heavily against the front edge of the cushion, for this may lead to discomfort and possible interference with the blood supply of the leg. The cushion must not project so far forward that it interferes with the free movement of the legs. It is desirable that the part of the cushion supporting the ischial tuberosities should be flat and disposed horizontally. One of the advantages of this is that it permits the operator to change his position readily during periods of relaxation, thus resting different muscle groups in turn and allowing transference of pressure from one part of the buttock to another during prolonged watches. In practice this has been found to minimize discomfort and fatigue. The cushion should be resilient, but the resilience should only be in a vertical plane as any lateral or fore-and-aft sway will lead to instability. The resilience should be of such a degree that the body weight, taken on the buttocks, is distributed over as large an area as possible, with the proviso that the maximum pressure remains over the ischial tuberosities. This last consideration is based on the observation that the skin in this area, unlike that surrounding it, is specially modified in blood supply to withstand prolonged pressure (Edwards and Duntley, 1939).

(*b*) The foot-rest should be placed so that the foot is maintained at right angles to the leg for, when they are at rest in this position, both the anterior and posterior groups of leg muscles are relaxed, and when exerting pressure both groups are contracting equally so that no undue strain is thrown on either group. The relation of the foot-rest to the seat must also be determined accurately, so that when the seat height is adjusted to the ocular height the knee angle will be in a position for exerting maximum counter-pressure.

(*c*) The back-rest should be so placed that it affords comfortable support to the body, allowing free movement of the spine, and so that maximum counter-pressure between it and a suitably placed foot-rest can be obtained without 'throw off' in instances when pressure has to be developed suddenly while the operator is manipulating controls. The transverse curve of the back-rest must conform to the anatomical curvature of the lumbar region, and the dimensions of the back-rest should permit the accommodation of individuals of varying sizes.

4. *Freedom from breakdown*.—Apart from the anthropometric, anatomical, and physiological requirements outlined above, there are mechanical factors which must be taken into consideration. The individual components of the seat assembly must be capable of withstanding very severe usage, and must be weather-proof, water-proof, fire-proof, rot-proof, oil-proof, and termite-proof. The construction of the seat must combine maximum strength with minimum weight and size, and must provide for easy maintenance. Finally, the design must not interfere with rapid access to, or escape from, the seat.

Dimensions and Design

1. *Anthropometric Data*.—The calculations for dimensions of the seat are based on the American Fort Knox survey of body measurements of military personnel. We used this survey as a standard reference for anthropometric data, because it was available before any British survey was published, and because the method of presentation of the data is particularly suited for use in the problems with which we are concerned. Recently we have compared this survey with the body measurements of British tank personnel obtained by the Department of Biological Research of the War Office with the collaboration of Dr. G. M. Morant and Prof. A. Bradford Hill, and, from the point of view of our investigations, there is no appreciable difference between selected groups of American and British subjects. On occasions when no relevant data were available, we obtained the required measurements ourselves from representative groups of individuals.

2. *Body Stabilization*.—For naval purposes, body stabilization is of prime importance; it was, therefore, given first consideration in the design of the

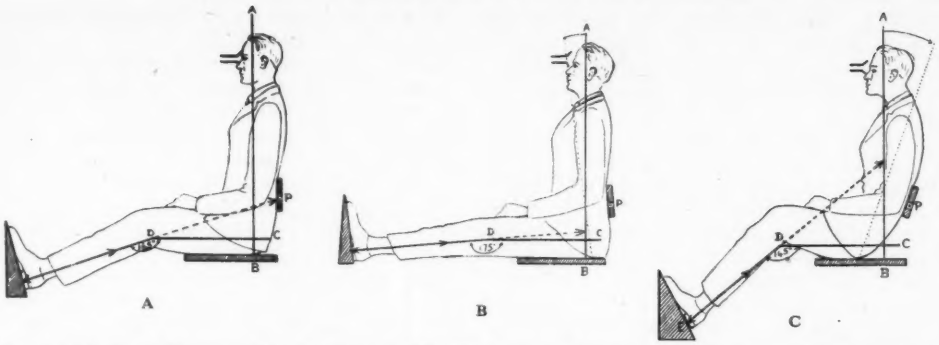

FIG. 1.—(*a*) The optimum position for body stabilization between foot-rest and back-rest. There is no eye displacement or tendency to 'throw off' when pressure is exerted. (*b*) The angle at the knee joint is too obtuse. The buttocks tend to get wedged between the seat and the back-rest. There is eye displacement and a tendency to 'throw off' when pressure is exerted. (*c*) The angle at the knee joint is too acute. The body tends to rise in the seat. There is eye displacement and a tendency to 'throw off' when pressure is exerted.

seat. Complete body stabilization can be obtained most satisfactorily without the use of any retaining mechanism. It can be achieved by counter-pressure between the feet against a foot-rest, and the back against a back-rest. Obviously, the position of the legs and body in which the maximum counter-pressure can be developed (provided it does not introduce any discomfort leading to fatigue) is the ideal one for stabilization. The more the position varies from the optimum, the greater the output of energy necessary to maintain equivalent pressures, since the muscles are working at a decreasing mechanical advantage. The optimum position of the foot-rest and back-rest in relation to the seat to obtain maximum counter-pressure was calculated from the results of direct experiment by Dr. Hugh-Jones on thrusts exertable on tank brake- and clutch-pedals. Previous work on naval problems had indicated that the thrust of the legs against a foot-rest rises with increasing knee angles. The work of Hugh-Jones went further and showed that, when the angle of the thigh to the body remains constant, the maximum thrust rises as the knee angle increases up to a well-defined 'limiting angle' of 165° to 170°, above which, as the knee straightens and then extends, the thrust obtainable falls precipitously. The explanation of this seems to be that, with a man of average bodily dimensions sitting in such a position, the line of thrust passes through the pivotal axis of the back-rest when the latter is in the optimum position. If the knee angle is smaller, the thrust is directed above the back-rest, so that when exerting pressure with the feet there is a tendency (which has to be restrained) for the upper part of the body to be pushed back. Conversely, if the knees are held at an angle greater than 165°, the thrust tends to incline the body forward. Both these movements result in instability and loss of counter-pressure (fig. 1 *a–c*). Recently, it has been shown that in cadavers the increase of tension resulting from increasing the knee angle may be due to the patella being drawn

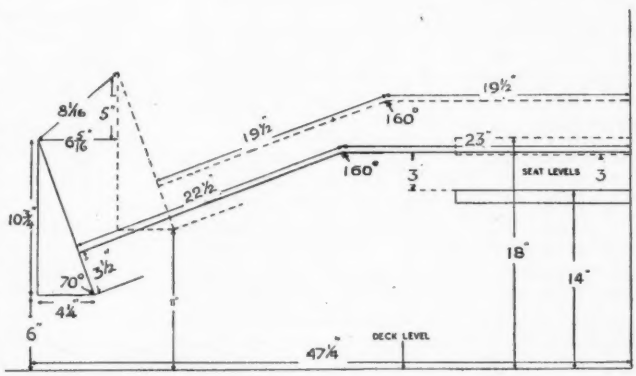

FIG. 2.—This gives the dimensions and range of adjustments in inches for a seat in which stabilization is effected between back- and foot-rests.

upwards over the femoral condyles and being displaced farther from the centre of the knee joint as the knee is extended, thus, allowing the quadriceps muscle to work at a greater mechanical advantage. (Haxton, 1945).

From the observations outlined above, it will be obvious that it is necessary to have a seat with an adjustable foot-rest so that in different individuals a knee angle of 160° can be obtained. In practice, an angle of 160° is aimed at, for when counter-pressure is developed the knee angle tends to increase, due to the 'give' in the seat pressure. In such a position the stability achieved is so great that a subject can easily remain in his seat when it is rolled over from side to side, even when less than the maximum counter-pressure is being exerted. In naval operations the maximum extrinsic force tending to displace an operator from his seat is estimated at about 200 lb., whereas the mean thrust possible with each leg is over 500 lb. (fig. 2).

3. *The seat cushion.*—The next important consideration is the design of the seat cushion. Reference to anthropometric data shows that the cushion should be at least 15 inches wide, and 18 inches deep. It is found that in practice a flat cushion is not completely satisfactory, for when the subject is sitting in the optimum position (that is, with upper surfaces of the thighs horizontal and the knee at an angle of 160°), the distal part of the underside of the thigh is not supported by the cushion, because it slopes upwards at an angle of about 10° to the horizontal in the average subject. To compensate for this, and at the same time to retain the advantage of a flat seat, the front 8 inches should be sloped at an angle of about 10° to the horizontal, and the back 10 inches disposed horizontally. It is essential that the front edge of the cushion should be softly sprung to prevent undue pressure on the underside of the thigh, and also to allow for any variation in the slope of the underside of the thigh in different individuals.

To obtain the correct resilience without fore-and-aft sway, we have found that the most suitable type of springing consists of flexible steel strips fixed transversely. Such springs have the added advantage that they can be made to give any required degree of resilience. Moreover, with this method of springing, the resilience does not vary even with prolonged use. Thus it enables an individual to adjust his seat to a given height, so that he is always in the correct position to operate his sight, gun, or other instrument. The selection of a suitable seat-covering proved somewhat difficult, but success has been achieved by the use of transversely fluted first-quality hide, overlying DDT-impregnated horsehair and stitched to treated hessian. Such a covering will stand arctic cold as well as tropical heat, and is comfortable to sit on when the only clothes worn are shorts and when sweat is abundant. In the past, first-quality hide was a staff requirement for officers' furniture only, whereas, of course, it should be fitted where it is subjected to the most severe usage.

The optimum height of the back-rest corresponds to the level of the maximum concavity of the lumbar curvature. The height of this level above the ischial tuberosities was determined in 50 male subjects, and in individuals within the 90 per cent. range of sitting height this was found to vary between 8 and 12 inches. It was thought at first that a back-rest which was adjustable in height would be necessary in order to give efficient support to the backs of all individuals, but practical tests showed that a back-rest 5 inches in vertical depth, with its centre 10 inches above the level of the compressed seat-cushion, was satisfactory.

It was also necessary to determine the position of the back-rest in relation to the back of the seat. To do this, the position of the maximum concavity of the lumbar curvature in relation to the most backwardly projecting part of the buttocks was measured in 50 persons sitting erect. It was found, on the average, that the lumbar spine at this level is half an inch behind the buttocks, and thus the back-rest should be placed half an inch behind the back of the seat. Practical tests on a further large series of individuals showed that such a position was satisfactory.

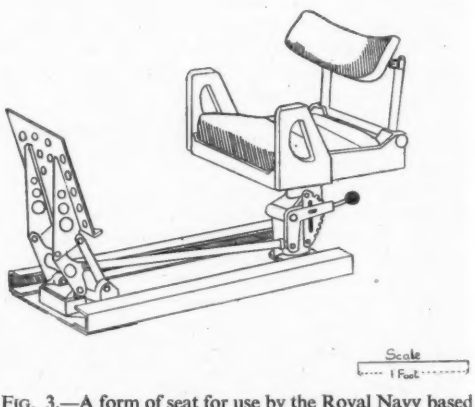

FIG. 3.—A form of seat for use by the Royal Navy based on the principles outlined in the text.

For efficient as well as comfortable support, the curve of the back-rest should correspond as accurately as possible to the natural curvature of the lumbar region in the horizontal plane. The average curvature in this plane was, therefore, determined in 25 subjects. Each individual was seated erect on a chair, and the curvature was measured 10 inches above the level of the seat, with and without the subject wearing winter clothing. The curves were recorded by means of a length of lead piping which was firmly moulded round the loins. The mean curve was only estimated for 4 inches on either side of the mid-line, and was found to be the arc of a circle of $7\frac{5}{16}$ inches radius, whatever the clothing worn. Beyond this distance, individual curves varied so greatly that it was impossible to estimate a practical mean curve, although their radii never exceeded $7\frac{1}{4}$ inches. It was, therefore, decided to construct a back-rest having a radius of $7\frac{5}{16}$ inches and a width of 15 inches. A 'mock-up' constructed from these data fitted all the subjects with a fair degree of accuracy, and, when sprung with steel strips fixed transversely and suitably covered with hide and horsehair, proved entirely satisfactory in all cases.

The position of the pivot of the back-rest is of importance if the latter is to follow easily the changing contour of the back when leaning forwards or backwards. It should, in all cases, be below the centre of the rest, because the force exerted against the back-rest by the counter-pressure of the feet is considerably greater than that derived from the upper part of the trunk.

5. *The foot-rest.*—The position of the foot-rest in relation to the seat was determined by considering the optimum position for body stabilization. The foot-rest must be long enough to support the largest booted foot, and wide enough to accommodate the feet in the most comfortable and efficient position for exerting pressure. To fulfil these requirements, it should be 14 inches long and 15 inches wide. A heel-rest should be provided at right angles to the foot-rest and this should be at least 3 inches deep. In order to accommodate a 90 per cent. range of subjects in the optimum position for body stabilization, the foot-rest must be adjustable. Fortunately, there is a good correlation between the leg-length and sitting-height, so that a link mechanism can be used which allows simultaneous adjustment of the seat and the foot-rest by moving a single lever.

6. *The lateral thigh supports.*—It was found that by fitting lateral thigh supports to the sides of the (seat in the front only) the comfort of the operator in the relaxed position was increased considerably. These prevent too great a degree of passive lateral rotation of the thighs, and so obviate strain on the adductor and medial rotator muscles, which must otherwise remain in a state of tonic contraction. These supports can be so placed that controls attached to them are in the correct position for precise manipulation by the hands. They can also be used as an aid to stabilization to some extent, if the thighs are forced against them. Fig. 3 illustrates a seat designed in accordance with the principles outlined above for use by the Royal Navy.

High-Angle Optical Sights

The increasing incidence of air attack on ships at sea during the war made the construction of high-angle ocular sights imperative. Although 'Radar' has revolutionized plane-spotting, ocular sights still have an important rôle to play. Until recently ocular sights for naval use have only been designed for low-angle observations, and, although satisfactory for this purpose, they are virtually impossible to use at high angles of elevation. The human mechanics concerned in the design had, therefore, to be determined before a satisfactory sight could be constructed for high-angle observations.

Desiderata

From the anatomical point of view, there are two factors which must be considered if binocular sights are to be used to the best advantage.

1. The position of the operator must be such that his eyes are related correctly to the binocular eyepieces, both in the vertical and horizontal plane. This necessitates the design of a seat which allows essential adjustment to be made with ease and rapidity.

2. The binocular movement must be such that it follows the natural track taken by the eyes during elevation.

Dimensions and Design

1. Practical tests showed that the vertical adjustment of the eyes to the binocular eyepieces is of extreme importance. For maximum efficiency, the optical axis of the eyes of the observer and of the binoculars must be coincident. A maladjustment of half an inch above or below the optimum level results in a serious decrease in the degree of elevation attainable by the observer. The sitting eye-height of the 90 per cent. range of subjects was found to vary between 30 and 34 inches. As it is not possible to alter the position of the binoculars for

observers of varying stature, the seat must be adjustable through the required range.

In addition, for maximum efficiency, the position of the binocular eyepieces should correspond to the normal position of the eyes when the observer is sitting erect in a natural manner and looking directly forwards. It was found by experiment that the natural position of the eyes in 50 individuals within the 90 per cent. range varied from 4½ to 6 inches in front of the vertical plane through the back-rest, the average being 5½ inches. Subsequent trials showed that with the eyepieces in the average position the mean maximum elevation without strain was greater than in other positions, but, providing the position of the eyepieces did not vary more than one inch on either side of the average, the decrease in the mean maximum elevation was insufficient to justify the incorporation of a special adjusting mechanism in the sight.

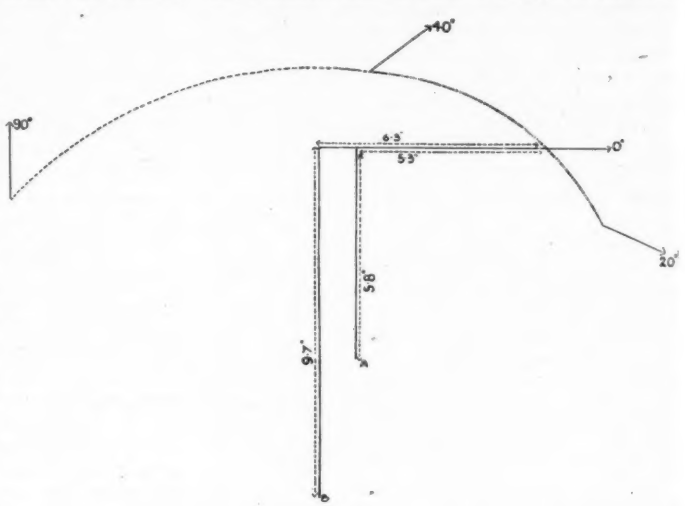

FIG. 4.—This shows the mean track of the eyes between 20° depression and zenith. The curve lies on the arcs of two circles with different centres (positions indicated) in relation to the front of the eyeball. The arrows indicate the lines of sight.

2. The method used to determine the natural track of the eyes from a position of maximum depression up to zenith was an extension of that previously adopted by the Admiralty Research Laboratory at Teddington, where the pivot of the low-angle sight was determined. Cinematograph films were taken, from a fixed position, of a number of seated subjects simulating the act of sighting from maximum depression to maximum elevation. The films were then projected, frame by frame, at a standard magnification, and the track of the eyes traced on to squared paper. The mean track of the eyes was determined by superimposing the tracings so obtained. The curve obtained by this method did not correspond with that taken by the binoculars in the case of the low-angle sight (Sight A—see Table). The track of the eyes is, in fact, found to describe two major curves with different centres. The first curve, which is described by the eyes from 20° depression to about 40° elevation, is centred in the region of the atlanto-occipital joint, and corresponds to a combination of head and neck movements; and the second, of longer radius, is described by the eyes above 40° elevation and is due chiefly to movements of the trunk (fig. 4). The oculars can be made to travel approximately along the track of the eyes by pivoting the sight at the centre of the mean of the two curves mentioned above, or more accurately, if a movable pivot is incorporated by operating through a cam mechanism so that the binocular eye-pieces actually follow the mean track of the eyes described from 20° depression to zenith (figs. 5*a* and *b*). When the first method, using the compromise pivot, was put to a practical

TABLE

Sight	60 degrees elevation without strain	90 degrees elevation without strain	Mean maximum elevation	
			Without strain	With strain
	Subjects	Subjects	Degrees	Degrees
A (low angle) ..	26	8	57	68
B (compromise pivot) ..	100	55	75	87
C (movable pivot) ..	100	90	78	89

test, it was found that a considerable improvement had been effected but that the low position of the pivotal point had certain mechanical disadvantages (Sight B, see Table). The second method, incorporating a movable pivot (Sight C, see Table), gave a further improvement in the range of elevation and had the added advantage that some existing low-angle sights could be modified to incorporate such a mechanism with the minimum of interference with the design. In order to determine the relative efficiencies of sights with pivotal points in different positions, the maximum elevation in each was determined in 100 unselected subjects of varying body dimensions within the 90 per cent. range. The Table shows the results obtained. The seat height was carefully adjusted for each subject before commencing the experiment. The oculars were fixed at 5½ inches from the centre of the back-rest.

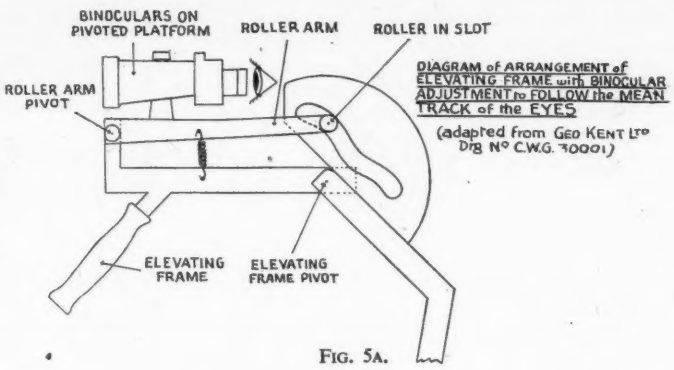
BINOCULARS ON PIVOTED PLATFORM
ROLLER ARM
ROLLER IN SLOT
ROLLER ARM PIVOT
DIAGRAM of ARRANGEMENT of ELEVATING FRAME with BINOCULAR ADJUSTMENT to FOLLOW the MEAN TRACK of the EYES
(adapted from GEO KENT Ltd Drg N° C.W.G. 30001)
ELEVATING FRAME
ELEVATING FRAME PIVOT

FIG. 5A.

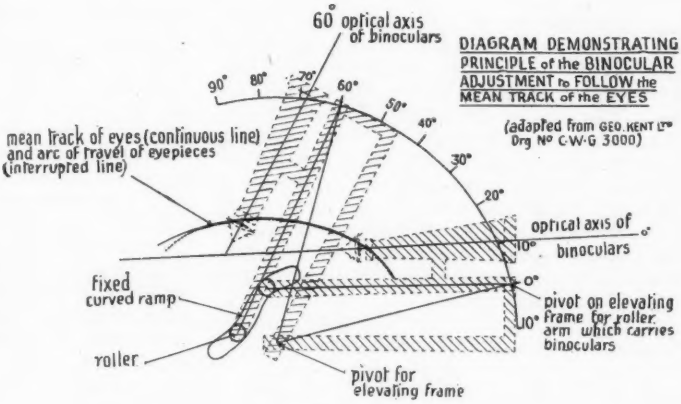
60° optical axis of binoculars
DIAGRAM DEMONSTRATING PRINCIPLE of the BINOCULAR ADJUSTMENT to FOLLOW the MEAN TRACK of the EYES
(adapted from GEO. KENT Ltd Drg N° C.W.G 3000)
90° 80° 70° 60° 50° 40° 30° 20° 10° 0° 10°
mean track of eyes (continuous line) and arc of travel of eyepieces (interrupted line)
optical axis of binoculars
fixed curved ramp
roller
pivot on elevating frame for roller arm which carries binoculars
pivot for elevating frame

FIG. 5B.

Summary and Conclusions

The machines used in modern warfare have become so complex, and their efficiency can be made so high, that the limiting factor in the accuracy of their operation is the man behind them. For this reason the human factors in engineering design have assumed great importance. Illustrations of the application of anatomical principles to the design of seats and sights for use by the Royal Navy have been given. It is clear that many of the anatomical problems of war are also those of peace, and that there is a large anatomical field yet to be explored.

We would like to express our thanks to the Royal Naval Personnel Research Committee of the Medical Research Council, under whose auspices work was carried out, and to the Medical Research Council for personal and equipment grants. We would also particularly like to thank Prof. W. E. Le Gros Clark, Dr. G. L. Brown, Lt.-Cmdr. C. E. J. Streatfield of the Experimental Department, H. M. S. *Excellent*, and Cmdr. E. J. Golby of the Admiralty Gunnery Establishment, for their personal aid and encouragement.

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DENTAL EROSION IN WORKERS EXPOSED TO INORGANIC ACID FUMES

BY

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Changes in the colour and structure of the teeth in workers exposed to strong inorganic acid fumes have, we believe, been recognized for many years by the workers themselves. Various measures of protection have, in fact, been unofficially adopted by them, and these we shall discuss below. Because these changes do not give rise to any loss of time or earnings, and because the affected workers have been reluctant in the past to report them, the prevalence of the condition has not been fully realized and no precautions have been adopted to prevent it. The dangers of acute nitrous fume poisoning are well known and guarded against.

In the course of routine medical examination of the workers in this factory the peculiar erosion of the teeth of certain workers was observed, and this led to a full dental examination of all workers engaged in the manufacture of guncotton and nitrocellulose and exposed continuously to acid fume. The workers had been employed in this section for periods varying from one month to five years. One hundred and eighteen female workers and eight males were examined. This preponderance of female workers was due to the fact that these women had taken over work formerly carried out by men.

The Process

The processes involved in the manufacture of guncotton and nitrocellulose are well described by Read (1942) in a recent popular treatise. At one stage the cotton waste or paper rolls (scrolls) which form the raw materials of these products are dipped in earthenware baths containing a mixture of approximately 70 per cent. sulphuric acid, 22 per cent. nitric acid, and 8 per cent. water. Dipping cotton waste requires considerable skill and time (20 minutes per bath). Dipping scrolls is much simpler and less heavy work, requiring only about two or three minutes. A greater number of dippings are done per shift in this case, so that the length of exposure to fume is about equal in the two processes. The bath of acid is covered by an aluminium hood, open at one side to allow the dipping to be carried out. The hood is fitted with an exhaust pipe to carry off acid fumes (fig. 1), but this exhaust does not completely exclude fume from escaping, and if decomposition occurs while the process is being carried out it is quite inadequate to deal with the heavy clouds of nitrous fumes that are formed. The worker stands at the open side of the hood and pushes cotton waste into the bath through the opening, and then dips this waste under the surface of the acid with an aluminium or stainless steel fork. Rubber gloves and eyeshields are provided to protect the hands and eyes from splashes. No mask is provided, since the hood and exhaust are considered adequate. If a " fire " occurs, with resultant nitrous fumes, the dipper steps aside and the " fire " is put out by a male worker who wears a respirator for this purpose. Unfortunately it is not easy for the dippers in the neighbourhood to move away, because unattended and incompletely dipped cotton waste will readily decompose.

It was customary for each female dipper to work half an 8-hour shift at dipping, and half a shift at trucking, i.e. pushing trucks loaded with wet washed nitrated cotton to the boiling vats where the next stage in the manufacture is undertaken. The general ventilation of the building was much impaired under black-out conditions. The men examined were engaged in the lifting and replacing of hoods and in dealing with emergencies.

Of the female workers examined, 26 had been employed for three months or less, and all of these had accurate dental records made before commencing work. There were 29 women who had

been working at the factory for periods varying between three months and one year, and all these with one exception had also initial dental records. A further 42 had been employed for periods from one to three and a half years without, in most cases, any initial dental records having been made. In addition to these groups, 21 workers had had total extractions carried out and dentures fitted during their period of employment at this work.

Results

The degree of erosion found in many of these workers varied considerably, generally in relation to length of exposure and the texture of the affected teeth (see Table 1). Pearly white teeth were more

TABLE 1
FEMALES: 118 EXAMINED; 21 WITH DENTURES

Time employed	Erosion	No erosion	Total	Percentage affected
1 to 3 months	6	20	26	23·1
3 months to 1 year ..	11	18	29	37·9
1 to 3½ years ..	26	16	42	61·9

readily affected. In all cases the teeth showing erosion were the upper and lower incisors, and in a few the canines were also involved. The erosion begins in the incisal third of the teeth and extends on the labial surface (fig. 2). There is no pitting and there is always, even in very advanced cases, a smooth, polished appearance (figs. 3 and 4). When the enamel has been destroyed the dentine is attacked and there is brown or blackish discolouration of the affected teeth, which still retain their polished appearance. The pulp chamber shrinks while this erosion is taking place, and the condition is quite painless unless the erosion is so rapid that bacterial invasion of the pulp chamber can occur, with abscess formation. This was observed in one female worker, who showed very rapid erosion of the upper central incisors within three months of starting work. None of the workers examined showed evidence of Vincent's or other infection of the gums.

Of the eight men examined, four, employed for periods varying between three months and five years, showed no evidence of erosion although showing ordinary dental decay. Two showed marked erosion (fig. 5), and two had had dentures fitted during their term in this employment. Since this investigation was carried out, one of us (J. B. L.) has noted similar erosion among male workers engaged in the manufacture of nitric and sulphuric acids.

Discussion

Erosion of the teeth due to acid has been recognized in the explosive and other industries both in this country and abroad. Legge (1934) has described dental erosion among workers exposed to hydrochloric acid fumes and to nitrate of mercury, noting in the latter type of exposure a characteristic erosion of the incisors and canines. Berenzon (1930) also noted erosion of the incisors in workers engaged in the manufacture of hydrochloric and picric acids. The condition described by him was quite painless and was present in greater or less degree in the 15 workers he examined. Erosion among acid dippers and other workers in explosive factories has also been recorded by observers in Canada and Italy (Simpson, 1919; Muzi, 1927). They describe a typical erosion of the exposed portions of the incisors, the labial surfaces being mainly affected. In a recent survey of the effects of occupation on the mouth, Schour and Sarnat (1942) state that erosion of the lingual surface of the incisors has been observed in cases of repeated vomiting, due presumably to the high acidity of the vomitus.

The site of erosion suggests to us the direct action of acid fume on those teeth exposed by talking or mouth breathing. The canines, premolars, and molars are apparently adequately protected by the salivary wash to which they are submitted, and this finding suggests that an increased salivary flow may assist in protecting the worker.

Several unofficial methods of protection were adopted by the workers. Two girls who showed no erosion were in the habit of brushing their teeth carefully at every opportunity, before and after shifts and at meal breaks; and, what is more important, they avoided talking as far as possible. Most workers relied on scarves padded with cotton waste tied round the mouth, and Table 2 shows the findings in this respect. From this it will be seen that the wearing of a mask had considerable significance in the percentage of erosion shown by the longer-employed workers.

TABLE 2
COMPARISON OF FINDINGS IN THOSE WORKERS WHO WORE SCARVES AND THOSE WHO DID NOT

Time employed	Mask			No mask		
	Number	Number showing erosion	%	Number	Number showing erosion	%
1–3 months ..	10	1	10	12	2	16·6
3 months–1 year	16	7	43·7	10	2	20
1–3½ years ..	16	7	43·7	23	18	78·26
Total	42	15	35·7	45	22	48·8

In peacetime, explosive manufacture men employed as dippers were in the habit of chewing cotton waste, thus inducing an increased flow of saliva; and this practice was, we have been informed, fairly successful as a protection.

Since the manufacture of guncotton and nitrocellulose has temporarily ceased, and the female workers have been declared redundant, there has been no opportunity to try out preventive measures on a large scale. The wearing of a close-fitting mask or a respirator is quite unsuitable owing to the discomfort that would arise after a short time, but a light face-shield of a visor pattern might be helpful and more easily endured. Periodical dental examinations should be carried out and workers showing rapid erosion excluded. Alkaline tablets could also be tried, both as an aid to inducing the increased salivary flow by the mechanical process of sucking, and as neutralizing agents. Excessive talking and singing should be discouraged, the reason for this being explained to the workers. Mouth breathers should be excluded from this work. The aim of prevention should be the redesigning of the process to exclude the escape of fume. More powerful exhausts are at present impracticable.

One striking feature is that, of all the workers examined, only two voluntarily reported the condition and both these workers were recent entrants who prided themselves on the appearance of their teeth. The absence of pain and incapacity may account for this apathy. The fact that 21 women required dentures during the period they were exposed may be significant: many of these workers stated that their teeth had been affected, and their descriptions accorded with the picture given above.

Summary

1. One hundred and twenty-six workers exposed to strong inorganic acid fumes were examined.

2. Forty-five of these showed erosion affecting mainly the incisor teeth. A description of the erosion is given.

3. The condition is discussed and preventive measures suggested.

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For Illustrations of this Article, see page 95.

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REACTION OF HUMAN BLOOD-FORMING TISSUES TO CHRONIC BENZENE EXPOSURE

BY

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For many years it has been generally believed that the clinical manifestations of chronic benzene poisoning in man are due to an aplasia of the blood-forming tissue in the bone marrow. This concept arose out of the pioneer experimental and clinical work of Santesson (1897) and of Selling (1910, 1916), and it is still widely held at the present time. It is the purpose of this paper to draw attention to the literature, which suggests that the reaction of the blood-forming tissues to benzene exposure is, in fact, much more varied, and to describe the case which first brought this literature to our notice. This subject is of some importance at the present time, when sternal puncture techniques are becoming increasingly used in the diagnosis of cases of intractable anaemia. In some of these cases failure correctly to attribute the cause to benzene exposure may stand in the way of measures being applied to reduce the hazard in the occupation responsible, and may also prevent a proper claim for compensation being established.

Review of the Literature

In a general review of the subject in 1931, Hamilton pointed out that the prevailing concept of chronic benzene poisoning in man was based very largely on the results of acute benzene poisoning in animals. That the conditions were not strictly comparable was suggested by the fact that animals usually showed a severe granular leucopenia with little or no anaemia, whereas anaemia is usually the most striking feature in man. Hamilton noted the paucity of recorded studies of human material, and drew attention to the variety of changes which had been reported as occurring in the blood-forming tissues. Some cases showed extensive extramedullary haemopoiesis: three cases had hyperplastic bone marrows. Hamilton concluded that a much wider concept of the results of benzene poisoning in man would have to be adopted as knowledge of the condition increased. It was not until 1939, however, that Mallory and others published an article which suggested that hyperplasia of the bone marrow with extensive extramedullary haemopoiesis might be quite a common result of chronic benzene poisoning in man. They made a study which included the histology of material from 19 cases, 14 being autopsies and 5 biopsies. Of these cases, 9 showed frank hyperplasia of the bone marrow, and in 5 the hyperplasia was described as marked. Only 6 showed hypoplasia, and no case of complete aplasia was seen. Haemopoiesis was frequently found in the liver, spleen, and lymph-nodes: and the liver and spleen were often greatly enlarged. In some cases the haemopoiesis was grossly atypical, and histological pictures resembling 'Hodgkin's sarcoma' were seen. There was a general parallelism in the degree and type of change found in the bone marrow and spleen of any one case. These authors give a full review of the literature, and an extensive bibliography from which the earlier references in this paper were obtained. They point out that our prevailing conceptions have been based to a large degree on studies of the changes in the peripheral blood which have been shown by a number of authors to furnish an unreliable index of the state of the bone marrow (Blumer, 1905; Thompson and others, 1935; Rhoades and Miller, 1938). Reference is made to 5 cases of benzene poisoning with hyperplastic bone marrow previously reported in the literature, and to a number of cases with various types of leukaemia. Of the 19 cases described by Mallory and others, 1 was an acute myeloid leukaemia with a typical leukaemic nodule in the liver, 1 a lymphoblastic leukaemia, and 1 an aleukaemic leukosis.

In 1940 Jackson and others described a syndrome under the title of 'agnogenic myeloid metaplasia' characterized by weakness, abdominal distress, and a haemorrhagic tendency, with progressive enlargement of the spleen, a moderately elevated or slightly depressed white cell count, and the constant presence of immature red and white cells in the peripheral blood. The spleens of all 10 cases described showed marked myeloid metaplasia, while the bone marrows were variously fibrotic, hyperplastic (1 case), aplastic, or normal. In no case was the marrow suggestive of leukaemia. Three of these patients were submitted to

splenectomy and all died within a year of operation; because of this the authors urge the importance of recognizing the condition as a distinct entity. The term 'agnogenic' was used to suggest ignorance of the cause of the condition.

Later Rawson and others (1941), noting the similarity of the histological findings and certain clinical features to those found in chronic benzene poisoning, made a special inquiry into the occupational histories of the 6 cases then attending their clinic diagnosed as agnogenic myeloid metaplasia. All 6 gave histories of many years' exposure to various industrial solvents, 3 to benzene, 1 to carbon tetrachloride, 1 to 'high test gasoline,' and 1 to a paint remover of unstated composition.

Case Report

The accounts of the occupational history and of the onset of the illness are drawn partly from the depositions of witnesses taken on oath at the inquest, copies of which were kindly sent to me by the coroner, Mr. G. F. E. Wilson, and partly from the history given by the patient when admitted to hospital. There are no major points of difference in these sources of information: where the exact dates differ, the depositions have been assumed to be correct.

Occupational History

The patient, a married man of 36 years, in 1937 began work supervising machines which spread cellulose resin in solvents on to cotton textiles. From 1937 until 1940 the solvent contained four parts pure benzene and one part industrial methylated spirits. In 1940 pure benzene became unobtainable, and benzol 90's (mainly benzene with less than 2 per cent. toluene and a trace of thiophene) was used as a substitute. From September, 1941, solutions of chlorinated rubber in benzol 90's were used also, and this formed a large proportion of the material with which he worked until April, 1942. After that date nitrocellulose solutions were spread intermittently in a solvent made up of benzol 90's five parts, mixed with methyl acetone three parts (methyl acetone consists of methyl alcohol, acetone, and methyl acetate, equal parts of each). Concurrently with the above benzene solvent used since 1942, cellulose acetate in methyl acetone solution was used in increasing proportions of the work, and the benzol preparations were used in decreasing amounts until the present time. The patient was thus exposed to benzene solvents constantly from 1937 to 1942 (5 years) and intermittently from 1942 until the onset of his illness in December, 1944 (2 years 8 months).

The spreading machines were fitted with hoods and ducts connecting with a suction fan for solvent recovery, and the workroom was said to be large and well-ventilated through wide doors and the roof. The patient was not required to wear a respirator when employed at his usual job. The widow stated that when he began to lose his appetite he told her, 'It's that benzene on my stomach.' She had frequently smelt benzene from his clothes, and even when he had changed his clothes she noticed the same smell in his breath. He had frequently complained about the benzene, and had described the workshop as 'laden with benzene fumes' in the period before 1942.

History of Onset of Illness

In December, 1944, the patient had an attack of tonsillitis and pharyngitis, and since then had suffered a gradually increasing tiredness, aching in the calves, palpitations, and throbbing in the head. At the end of January, 1945, his wife noticed that he began to lose his colour and energy. He became irritable and lost his appetite. At the end of May, 1945, his movements became difficult and his wife persuaded him to see his doctor, who told him that he had anaemia. A blood count on June 12, 1945, gave the following results: Hb 40 per cent. (5·9 g. per 100 c.cm.); red blood cells, 1,600,000 per c.mm.; colour index, 1·25; white blood cells, 2,600 per c.mm.; neutrophil polymorphs 7 per cent.; lymphocytes 78 per cent.; monocytes 1 per cent.; eosinophils 1 per cent.; metamyelocytes 12 per cent.; myeloblasts 1 per cent. The film showed slight anisocytosis and polychromasia, with a small number of stipple-cells.

He was treated with anahaemin, hog stomach extract, iron, and dilute hydrochloric acid, and made no progress. On July 9, 1945, his count was: Hb 30 per cent. (4·4 g. per 100 c.cm.); red blood cells 1,200,000 per c.mm. On July 11 he was admitted to hospital for further investigation and treatment.

Clinical State on Admission

The following information has been abstracted from the notes written by Dr. C. Atkinson.

Present Complaint.—He complained of tiredness and weakness (before coming to hospital he had become too weak to shave). Appetite was good but soon satisfied. He had lost 8 lb. in the last six months. He had had a slight cough during the past three days. There was no dyspnoea. Micturition and bowel action were normal, and there were no haemorrhoids.

Previous History.—The doctor who examined him for an insurance policy shortly after he began his employment in 1937 remarked on his fine physical standard. The patient had pneumonia in 1942.

Family History.—Both parents were living and well. His wife and three children were all living and well.

Clinical Examination.—The patient was very pale, edentulous, and had an area of herpes labialis which had been present three days. The tongue was slightly furred. The pulse was regular, rate 94, 'water-hammer' type, the blood pressure 150/50, the apex beat not localized, and there was a soft systolic murmur at the apex. The chest was barrel-shaped with equal expansion on the two sides, and very resonant everywhere; there was prolonged expiration and râles and rhonchi were heard in all regions. The abdomen felt 'doughy'; there was no rigidity and no tenderness. The spleen was thought to be felt one finger's breadth below the costal margin, but not with any certainty. The liver was not palpable. No palpable lymph nodes were found, and no abnormal signs in the nervous system.

The patient was given one pint of stored blood on July 12, 1945, and another on July 20.

Special Investigations

On July 24, 1945, the blood picture was: Hb 40 per cent. (5·9 g. per 100 c.cm.); red blood cells, 2,000,000 per c.mm.; colour index 1·0; nucleated cell count 3,000 per c.mm.; neutrophil polymorphs 4 per cent.; lymphocytes 81 per cent.; monocytes 2 per cent.; eosinophils 1 per cent.; basophils 1 per cent; metamyelocytes 3 per cent.; myelocytes 1 per cent.; myeloblasts 2 per cent.; normoblasts 5 per cent. The film showed slight anisocytosis and polychromasia. The mean corpuscular haemoglobin concentration (M.C.H.C.) was 31 per cent. (normal 32 to 38 per cent.). The mean corpuscular volume (M.C.V.) was 95 cu. microns (normal 78 to 94 cu. microns). The serum bilirubin was less than 0·1 mg. per 100 c.cm. The fractional test meal showed free HCl in most specimens with 40 c.cm. N/10 HCl per cent. of the fasting juice, falling off to zero in the last two specimens: no histamine was used. The blood Wassermann reaction was negative. On July 7, 1945, platelets numbered 85,000 per c.mm. On July 18, 1945, *x* ray of the chest showed moderate generalized peribronchial thickening with some degree of bronchitis; the apices were clear, the air entry was good, and no other changes were seen. The urinary sulphates were not investigated, seven months having elapsed since his last exposure to benzene.

A sternal puncture was performed on August 21, 1945, and again on December 21, 1945. The smears and cell counts gave results as in Table 1 (terminology of Doan Sabin and Cunningham; normal values from Whitby and Britton's *Disorders of the Blood*, fourth edition). These counts both show a marrow with marked hyperplasia of the erythroid elements, with failure of maturation of both erythroid and myeloid cells. Mitoses were infrequent. On each occasion 400 cells were counted.

TABLE 1

Cells	Patient A 21.8.45	Patient B 21.12.45	Normal C
Total nucleated cells per c.mm.	300,000	300,000	25,000–100,000
Differential nucleated cell count percentages:			
Neutrophil:			
polymorphs	0·25	1·75	22·0–50·0
metamyelocytes	1·0	0·5	2·5–12·0
myelocytes	10·0	7·5	2·0–8·0
Eosinophil:			
polymorphs	0·25	0	0–4·0
myelocytes	6·25	1·25	0–3·5
Basophil myelocytes	0·25	0	—
Premyelocytes	6·5	6·75	0·5–5·0
Myeloblasts	5·5	7·25	0–2·5
Lymphocytes	11·75	7·0	5·0–20·0
Monocytes	—	0·75	0–5·0
Normoblasts	14·25	25·75	7·0–19·0
Erythroblasts	25·75	27·5	2·0–7·0
Megaloblasts	17·5	14·0	0–4·0
Megakaryocytes	0·25	0	—
Turk cells	0·5	0	—
Ratio: myeloid cells / nucleated erythroid cells	0·45	0·37	2·0–8·0

Treatment

During his three months' stay in hospital, he received at various times courses of full doses of the following preparations: anahaemin, 'gastrexo', ferrous sulphate tablets, with dilute hydrochloric acid, ascorbic acid (orally), and 'adexolin'. He also had an eight-day course of pentose nucleotide 10 c.cm. intramuscularly twice a day. The anahaemin was given in a dose of 2 c.cm. daily throughout this three months. During the last month he received also proteolysed liver, 1 oz. daily. There was never any sign that these preparations had any effect on his condition. As each was proved ineffective, the blood picture was restored by blood transfusion and finally brought to 105 per cent. Hb (15·4 g. per 100 c.cm.), and 5,000,000 red blood cells on October 20, 1945.

The patient was discharged on October 27, 1945, with his Hb and red blood cells still at this level. Altogether 6 bottles (each 420 c.cm.) of whole blood and 9 (each of 500 c.cm.) of packed blood cells had been given. He continued to receive 2 c.cm. anahaemin daily under the care of his doctor. His condition rapidly deteriorated, as is shown by the estimation in Table 2.

TABLE 2

Date	Hb.	Red blood cells per c.mm.
30.10.45	100 per cent. (14·7 g. per 100 c.cm.)	4,600,000
7.11.45	82 per cent. (12·0 g. per 100 c.cm.)	4,200,000
12.11.45	65 per cent. (9·6 g. per 100 c.cm.)	4,000,000
26.11.45	40 per cent. (5·9 g. per 100 c.cm.)	2,300,000

He was readmitted to hospital on November 27, 1945.

Condition on Readmission

The patient now had a carbuncle in the left temporal region and a large deep abscess in the left deltoid muscle at the site of an injection. There were diffuse purpuric spots scattered over the limbs and trunk, but no ecchymoses. The liver was thought to be enlarged, with its edge three finger breadths below the costal margin. The spleen was not palpable, and there were no palpable lymph nodes. The other findings were the same as before.

Developments Preceding Death

On readmission the patient was given a bottle of packed blood cells (500 c.cm.), his deltoid abscess was

incised, and systemic penicillin was administered. The abscess and carbuncle resolved. A series of blood transfusions was started, and he also received 'hepatex,' proteolysed liver, and vitamin preparations daily. On December 5, 1945, the coagulation time was two and a half minutes at room temperature (capillary method), and the bleeding time two minutes (Duke's method). A second sternal puncture was performed on December 21, 1945. The results are shown in Table 1, column B. No more purpuric spots appeared, and he seemed generally to improve until December 23, 1945, when a fairly severe epistaxis began, and continued as a steady ooze for two days. From this time his condition deteriorated rapidly.

On December 31, 1945, the blood picture was: Hb 45 per cent. (6·6 g. per 100 c.cm.); red blood cells 2,700,000 per c.mm.; colour index 0·85; reticulocytes 12 per cent. of total red blood cells; total nucleated cells 9,000 per c.mm.; polymorphs 3 per cent.; lymphocytes 39 per cent.; monocytes 2 per cent.; eosinophils 1 per cent.; metamyelocytes 13 per cent.; myelocytes 4 per cent.; premyelocytes 6 per cent.; myeloblasts 6 per cent.; normoblasts 26 per cent. of total nucleated cells. The film showed marked anisocytosis. The red cells were a good colour, and only a very occasional polychromatic cell was seen. Platelets were extremely scanty.

On January 5, 1946, the blood picture was: Hb 52 per cent.; red blood cells 2,800,000 per c.mm.; colour index 0·9; reticulocytes 3 per cent; total nucleated cells 14,000 per c.mm.; polymorphs 2 per cent.; lymphocytes 43 per cent.; monocytes 3 per cent.; basophils 1 per cent.; metamyelocytes 11 per cent.; myelocytes 20 per cent.; myeloblasts 8 per cent.; eosinophil myelocytes 3 per cent.; normoblasts 9 per cent. of total nucleated cells.

At about this time he developed a cellulitis of the pinna, which resolved with fomentation. A few days later he became dyspnoeic, and on January 9, 1946, complained of great thirst. The patient died at 7 a.m. on January 10, 1946. He had received 6 bottles (each 420 c.cm.) of fresh whole blood, 2 of stored blood, and 1 (500 c.cm.) of packed blood cells since readmission on November 27, 1945.

Post-Mortem Examination

An autopsy was performed, as soon as permission had been obtained from the coroner, on January 11, 1946, twenty-eight hours after death. The body was not stored in a refrigerator, none being available.

External Examination

The body was of a rather thin, middle-aged man. There were a small number of petechiae and small ecchymoses on the neck, thorax, and abdomen. There was a large ecchymosis 2 in. in diameter under the skin of the right arm. Small very firm lymph nodes were palpable in the axillae and groins. Orifices were normal. Testes were in the scrotum and felt normal. Rigor mortis was present, and there were hypostases posteriorly.

Internal Examination

Cardiovascular System.—The pericardium was normal. The heart as a whole was slightly enlarged. Epicardium: there were a few small scattered petechiae over the surface of the right auricle and ventricle. The myocardium was pale and flabby, but not at all abnormally friable. Endocardium: there were two small petechiae on the interventricular septum, under the endocardium of the left ventricle; valves were all normal, and the chambers all dilated and filled with abundant 'chicken-fat' clot.

The great veins were normal, and the pulmonary arteries completely filled with 'chicken-fat' clot. The aorta showed only slight atheroma. Other large arteries and coronary arteries also showed slight atheroma.

Respiratory System.—There were a number of avascular fibrous adhesions at the apex and mid-zone of the right side of the pleurae, but nothing else abnormal. The left side was normal. Both lungs were rather bulky, containing a slight excess of fluid. The lung parenchyma was a light brown colour with widely separated areas of anthracosis. There was an acute abscess, 1 inch in diameter, containing thick green pus in the upper lobe of the left lung in the mid-zone. A pure culture of coliform organisms was obtained from the pus. Larynx, trachea, and bronchi were normal; the bronchi contained brown frothy fluid (inhaled vomit).

Alimentary Systems.—The peritoneum was normal. The lips were pale. The mouth was edentulous, with upper and lower dentures, and the tongue showed several small submucous petechiae. The tonsils were slightly enlarged and covered with small areas of haemorrhage. The pharynx also showed several submucous haemorrhages, but was otherwise normal. The oesophagus was normal. The stomach was greatly distended with about 2 pints of opaque, brown, watery fluid, but was otherwise normal. The pylorus and duodenum were normal. The small intestine was moderately distended with brown, watery fluid. The appendix was normal. The caecum and large intestine were normal, containing soft, dark brown faeces. The liver was almost twice normal size, and pale; the enlargement was symmetrical. The liver substance was pale brown throughout, and very firm to cut. The gall-bladder and bile ducts were normal, and there were no stones. The pancreas was normal.

Haemopoietic System.—The spleen was three to four times normal size, the capsule smooth, the pulp greyish red with no sign of normal pattern: it was rather soft, wet, and friable. Lymph nodes in all regions were slightly enlarged and firm, with greyish-red cut surfaces. The sternal marrow and that at the lower end of the right femur were both greyish-red and firm; no medullary tumours were present at these sites.

Genito-urinary System.—The kidneys were both about twice normal size; the capsules stripped easily; the renal parenchyma was very pale, almost white in places, with only small areas of normal pattern; complete medullary rays were replaced by areas of firm white tissue. Both pelves showed submucous haemorrhages. The kidneys were alike in every respect. The ureters, bladder, and prostate were normal. The testes were in the scrotum and felt normal.

Endocrine System.—The sella turcica contained free blood, and the pituitary body was very soft, wet, and pale. The thyroid and adrenals were normal.

Nervous System.—The scalp and skull were normal. There was a small amount of haemorrhage in the subdural space over the vertex. The brain appeared normal in every respect. Table 3 gives the weights of organs.

TABLE 3

Organs	Weights in g.	Range of normal (Ross, 1939)
Brain	1,340	1,250–1,275
Right lung	940	480–680
Left lung	1,020	420–600
Liver	2,740	1,440–1,680
Spleen	570	155–195
Heart	398	250–280
Right kidney	284	140
Left kidney	312	150

Principal Morbid Anatomical Findings

The principal morbid anatomical findings were: (1) pallor and considerable enlargement of liver, spleen, and kidneys; (2) greyish-red firm bone marrow in sternum and lower end of femur; (3) slight generalized enlargement of lymph nodes; (4) acute abscess in the left lung; (5) dilated stomach containing 2 pints of fluid; (6) multiple petechial haemorrhages and small ecchymoses widely distributed throughout the body.

Histology and Cytology of Tissues

Blocks of tissue were taken from the following organs: heart; trachea, lungs (4); tonsil, pancreas, liver (2); spleen, cervical lymph nodes (right jugular chain) (2); bone marrow from sternum and lower end of right femur; kidneys (2); thyroid, adrenal, brain (2). All tissues removed at autopsy were cut into slices about 0·5 cm. thick, and fixed immediately in Zenker's fluid (with 10 per cent. acetic acid). From each block sections were cut and stained respectively with: (a) Harris's haematoxylin and eosin; (b) Geimsa (Wolbach's method modified); (c) Weigert's haematoxylin and van Geisen's collagen stain; (d) Turnbull's stain for iron.

In every organ studied the blood vessels of all sizes were dilated, and almost every one was filled with a sheet of contiguous nucleated primitive blood cells, no mature erythrocytes being seen. In the brain (fig. 1), peri-adrenal tissues, and pancreas, however, there were a minority of vessels which each contained a mass of primitive blood cells filling one half of the lumen, the other half being occupied by erythrocytes and fibrin. A few vessels were seen in these situations which contained only mature erythrocytes. About 90 per cent. of the primitive blood cells were large (one and a half to twice the diameter of the erythrocytes seen in the same section), with large round or oval nuclei each showing a fine, open chromatin network with one or more nucleoli; and a faintly basophil cytoplasm, which in the majority of these cells showed no discrete granules. These cells were thought to be myeloblasts. There were numbers of similar cells which showed fine granularity of the cytoplasm, and a few had indented nuclei (premyelocytes and myelocytes). Smaller numbers of cells were seen with smaller round or oval nuclei, a much denser and closer mesh chromatin network, and usually a darker, basophil, non-granular cytoplasm: these were interpreted as erythroblasts. Recognizable normoblasts with pyknotic nuclei were seen in small numbers, and occasional eosinophil myelocytes also.

Large interstitial collections of primitive blood cells, mostly of the myeloid series, were seen in the sections of lungs, tonsil, liver, lymph nodes, spleen, kidneys, and peri-adrenal tissues. In the spleen (fig. 2), lymph nodes (fig. 3), and tonsil (fig. 4), these collections were massive and formed the main bulk of the tissue in the section, but some remaining lymphoid tissue was still seen, in the spleen around the central arterioles, and in the lymph nodes and tonsil as widely separated small lymphoid follicles. In many places in the kidney areas of primitive blood cells widely separated the renal elements; similar areas were seen in the lungs and in the periportal regions of the liver. In all these sites the overwhelmingly predominant cell was the myeloblast, with smaller numbers of myelocytes, erythroblasts, and eosinophil myelocytes. Erythroblasts were more numerous in the tonsil than elsewhere. Mitoses were seen in fair numbers in the cell masses in the lymph nodes and kidney, and the latter showed also small numbers of mononuclear giant cells.

There was massive necrosis of the parenchymal cells of the liver (fig. 5) and of the renal (fig. 6) convoluted tubules. The liver cells showed only faint outlines of a nucleus, or none at all (karyolysis): their cytoplasm was mostly pink and coarsely granular (haematoxylin and eosin stain), containing some fine yellow pigment granules and showing a trace of fine blue granularity with Turnbull's iron stain. The convoluted tubules of the kidney all showed almost complete karyolysis, only traces of cell nuclei being seen. The cells were coarsely granular, with no definite margins. The lumina of the great majority of the convoluted tubules were obliterated by granular epithelial-cell débris.

The loops of Henle and collecting tubules were much better preserved. The cell nuclei stained normally, but their cytoplasm was granular and the cells had shrunk away from their basement membranes. The glomerular capillary tufts were plump and rounded, with a variable degree of segmentation. The capsular spaces all contained desquamated capsular epithelium.

The heart muscle showed severe fragmentation of the muscle fibres. There was no sign of excessive siderosis in any of the tissues studied. The sternal bone marrow (fig. 7) and that from the lower end of the right femur (fig. 8) presented identical histological features. Both showed the greatest possible degree of hyperplasia, with sheets of contiguous primitive blood cells completely filling the spaces between the bone trabeculae (except for narrow, clear, peripheral zones apparently formed by retraction of the cell masses). There was no sign of fatty, fibrous, or other non-haemopoietic tissue in these

spaces in any of the marrow sections. The haemopoietic tissue showed no obvious qualitative deviation from the picture seen in the sternal puncture smears.

Discussion

The case here described had a history of 5 years' daily exposure to benzene, followed by 2 years 8 months of intermittent exposure. At the end of this time the man became ill with a severe refractory anaemia, accompanied by a diminution in numbers of the leucocytes and platelets, and with variable numbers of primitive cells of both red- and white-cell series in the circulation.

Sternal puncture showed a hyperplastic marrow with erythroid elements predominating, and failure of maturation of both the erythroid and myeloid series of cells.

At autopsy the bone-marrow hyperplasia was confirmed, and histological studies showed extensive areas of both myeloid and erythroid haemopoiesis in the spleen, lymph nodes, tonsils, kidney, liver, lung, and peri-adrenal tissues. The histological picture was not that of a leukaemia, the primitive cells being far too heterogeneous, and the follicular structure of the lymphoid organs being too well preserved. It corresponded more closely with the histology of some of the organs described by Mallory and others (1939) in their cases of benzene poisoning; and even more closely with that described by Jackson and others (1940) as characteristic of the condition they termed 'agnogenic myeloid metaplasia,' some cases of which have been shown to follow prolonged exposure to benzene.

The evidence that the case here described was due to benzene poisoning is, as with all others so diagnosed, only circumstantial, but, when considered in relation to the other cases quoted from the literature, t would appear to be convincing.

The fact that the patient became ill during a period of reduced benzene exposure is not evidence against the idea that benzene was the causal agent. Smith (1943) described a case of fatal benzene poisoning with its onset in the fourth year after the last exposure, and he found 5 earlier cases in the literature where an interval elapsed between the last exposure and the onset of symptoms: in 2 of these the interval was ten years. The extreme individual variations in the relation between intensity and period of exposure, and the clinical consequences are well known.

Several features in the microscopical findings merit discussion. In the first place, the identity of the various primitive blood cells in the tissues and vessels in material fixed twenty-eight hours after death is not easy to establish with certainty. In particular, the most numerous cells, which have been interpreted as myeloblasts for the reasons stated, may in fact have been 'blast' cells of another kind. That they were very early blood-forming cells of one sort or another seems beyond reasonable doubt.

The appearances in the blood vessels everywhere suggested a terminal outpouring of primitive blood cells in enormous numbers from the tissues into the circulation, until they greatly outnumbered the circulating erythrocytes, followed by a post-mortem settling of the nucleated cells below the erythrocytes in some of the vessels. Some suggestion of the beginning of this process may be seen in the nucleated cell counts, which rose from 3,000 in July, 1945, to 9,000 on December 31, 1945, and to 14,000 on January 5, 1946, the increase being due mainly to the appearance of increasing numbers of primitive cells of both series. That there was time for settling of the cells before clotting occurred is shown by the presence of 'chicken-fat' clot in the heart.

The gross degenerative and necrotic changes in the liver, kidney, and myocardium were too severe and too extensive to have preceded death by more than a few hours. It is suggested that they were the result of a terminal anoxia produced by the rapid outpouring of primitive blood cells into the circulation, leading to an increased blood viscosity, diminished blood flow, and a dilution of the already reduced numbers of erythrocytes.

Summary

The clinical and pathological condition of a man who developed an intractable anæmia, leucopenia, and thrombocytopenia following many years' exposure to benzene solvents is described.

He proved to have a grossly hyperplastic bone marrow, with extensive areas of extramedullary hæmopoiesis.

The literature which suggests that this may be a common reaction to benzene exposure is reviewed.

The author wishes to express thanks to Dr. R. G. Howat for access to the clinical notes, to Mr. S. F. Moores for technical assistance, and to Mr. F. A. Murray, who prepared the photomicrographs.

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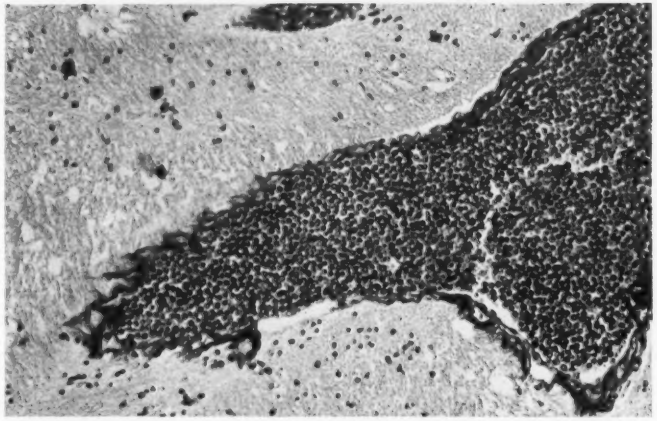

FIG. 1.—Brain, showing venule and capillary stuffed with primitive blood cells (all intravascular cells shown are nucleated). (× 120.

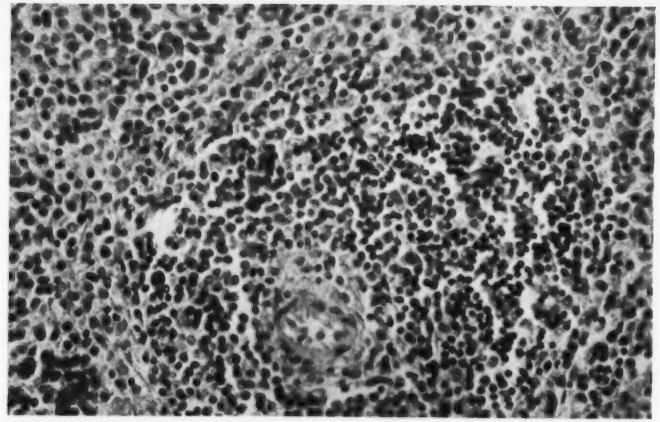

FIG. 2.—Spleen, showing myeloid cells in red and white pulp. (× 170.)

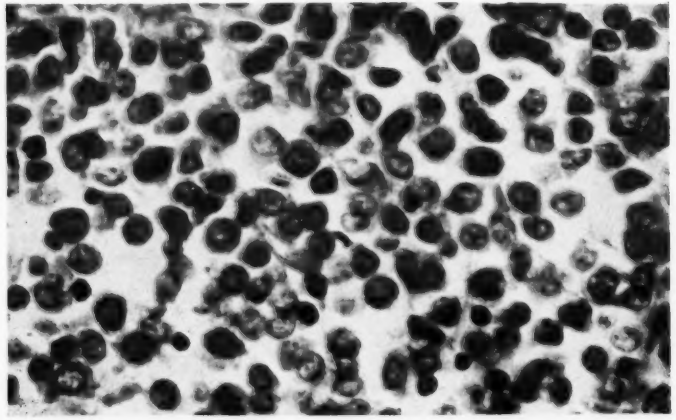

FIG. 3.—A typical high-power field of a lymph node. (× 650.)

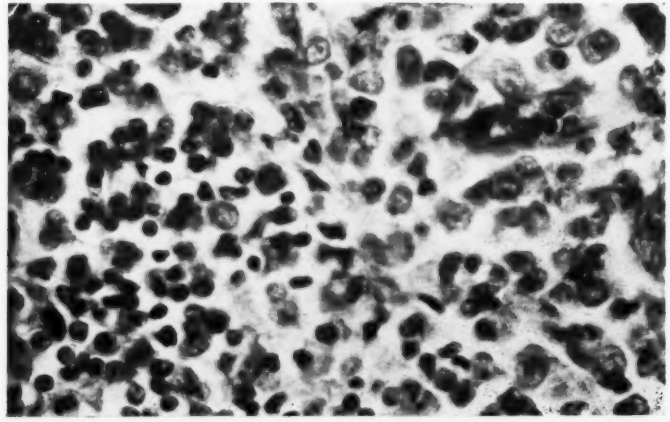

FIG. 4.—A typical high-power field of the tonsils. (× 650.)

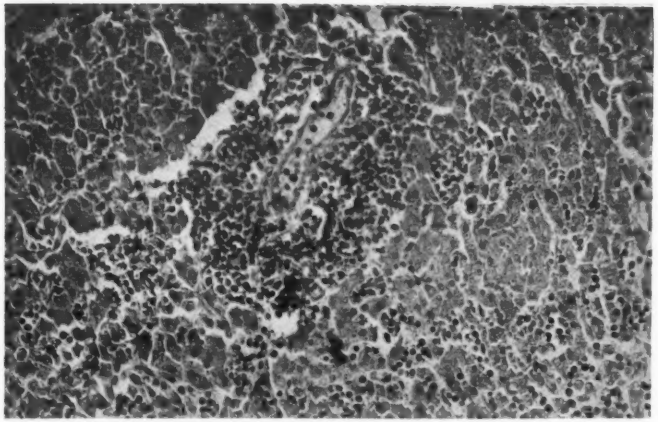

FIG. 5.—Liver, showing necrosis of parenchymal cells. There are lymphocytes and primitive blood cells in the portal area and in sinusoids. (× 120.)

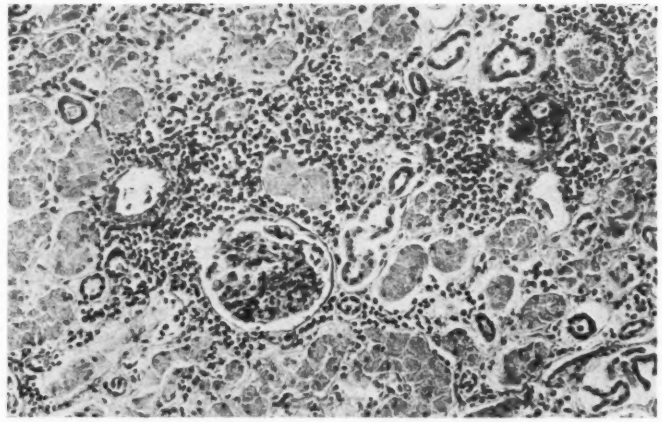

FIG. 6.—Kidney, showing necrosis of convoluted tubules and interstitial masses of primitive blood cells. (× 120.)

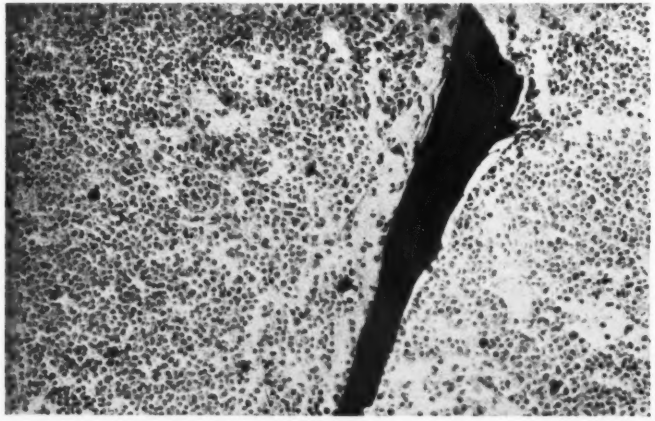

FIG. 7.—Sternal marrow. (× 120.)

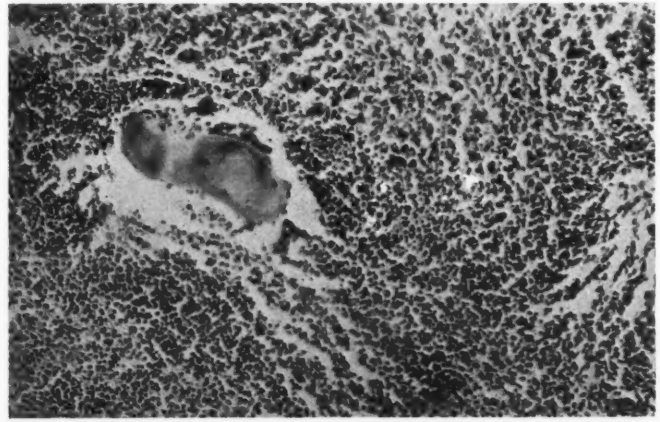

FIG. 8.—Femoral marrow. (× 120.)

FIG. 7.—Sternal marrow. (× 120.)

FIG. 8.—Femoral marrow. (× 120.)

FIG. 1.—Operatives in nitrocellulose nitrating house. Baths and hoods are shown

FIG. 2.—The teeth of a female dipper in the guncotton section after three months' work. There is early erosion affecting the lower incisors and lower left canine. The edges and labial surfaces are typically eroded. The excellent condition of the unaffected teeth is clearly seen.

FIG. 3.—Advanced erosion of central upper and lower incisors in a female dipper after two and a half years' employment.

FIG. 4.—Female after three years' exposure. The upper dentures were fitted while engaged at this work. Note the polished appearance of the eroded incisors and the good appearance of the premolars.

FIG. 5.—Male after five years' exposure. Advanced erosion affecting labial surfaces only.

Job Analysis Master Chart.

Job Number.	Job.	Sex: Male only	Sex: Female only	Sex: Male or Female	Skill: Skilled	Skill: Semi-skilled	Skill: Unskilled	Seeing: Distant vision Good	Seeing: Medium	Seeing: Poor	Seeing: Near vision Good	Seeing: Medium	Seeing: Poor	Seeing: Glasses permitted	Seeing: One eye safe & adequate	Hearing: Good	Hearing: Medium	Hearing: Poor	Hearing: No Reading No. Writing	Fingers & Hands: Hands, Full use Both	Fingers & Hands: " " One	Fingers & Hands: " " Neither	Fingers & Hands: Finger grip, one required	Fingers & Hands: " " , Neither "	Fingers & Hands: Hand grip, one	Fingers & Hands: " " , Neither "	Fingers & Hands: One hand adequate.	Arms: Arms, Full use Both	Arms: " " One	Arms: " " Neither	Arms: Flexion one only	Arms: " " Neither	Arms: Reach - Any
		X	1	2	3	S	1	2	3	A	1	2	3	4	5	6	7	8	B	1	2	3	4	5	6	7	8	C	1	2	3	4	5	6
1	Acetylene Cutter																																	
2	Acetylene Gas Producer																																	
3	Accumulator Attendant																																	
4	Acid Cleaner or Dipper					✓	✓			✓											✓								✓					
5	Ambulance Dept. Staff				✓	✓	✓				✓		✓							✓									✓					
6	Anodiser																																	
7	Arch (Bar) Loader						✓	✓						✓				✓		✓				✓				✓						
8	Arch (Bar) Operator						✓	✓					✓					✓			✓							✓						
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12																																		
13	Bar Straightener																																	
14	Battery Charging									✓					✓					✓									✓					
15	Beltman						✓	✓			✓			✓					✓	✓									✓					
16	Blacksmith (Millwright)					✓	✓			✓				✓				✓		✓									✓					
17	Bodymaker					✓				✓				✓				✓		✓									✓					
18	Body Mounter					✓	✓			✓				✓				✓		✓									✓					
19	Boilerman						✓	✓			✓			✓				✓		✓									✓					
20	Borer, Horizontal					✓	✓			✓				✓				✓		✓									✓					
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23	" Vert. Cylind[r]					✓	✓			✓				✓				✓		✓									✓					
24	Brazer																																	
25	Brinell Tester						✓	✓			✓			✓				✓		✓									✓					
26	Broacher						✓	✓			✓			✓				✓		✓									✓					
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41	Car Finisher Final					✓	✓				✓			✓				✓			✓								✓					
42	Car Inspector					✓				✓	✓			✓				✓			✓								✓					
43	Car Kitter or Rigger						✓			✓	✓			✓				✓			✓								✓					
44	Car Tester					✓			✓	✓			✓					✓			✓								✓					
45	Car Washer						✓			✓	✓			✓				✓			✓								✓					
46	Carburiser						✓			✓	✓			✓				✓			✓								✓					
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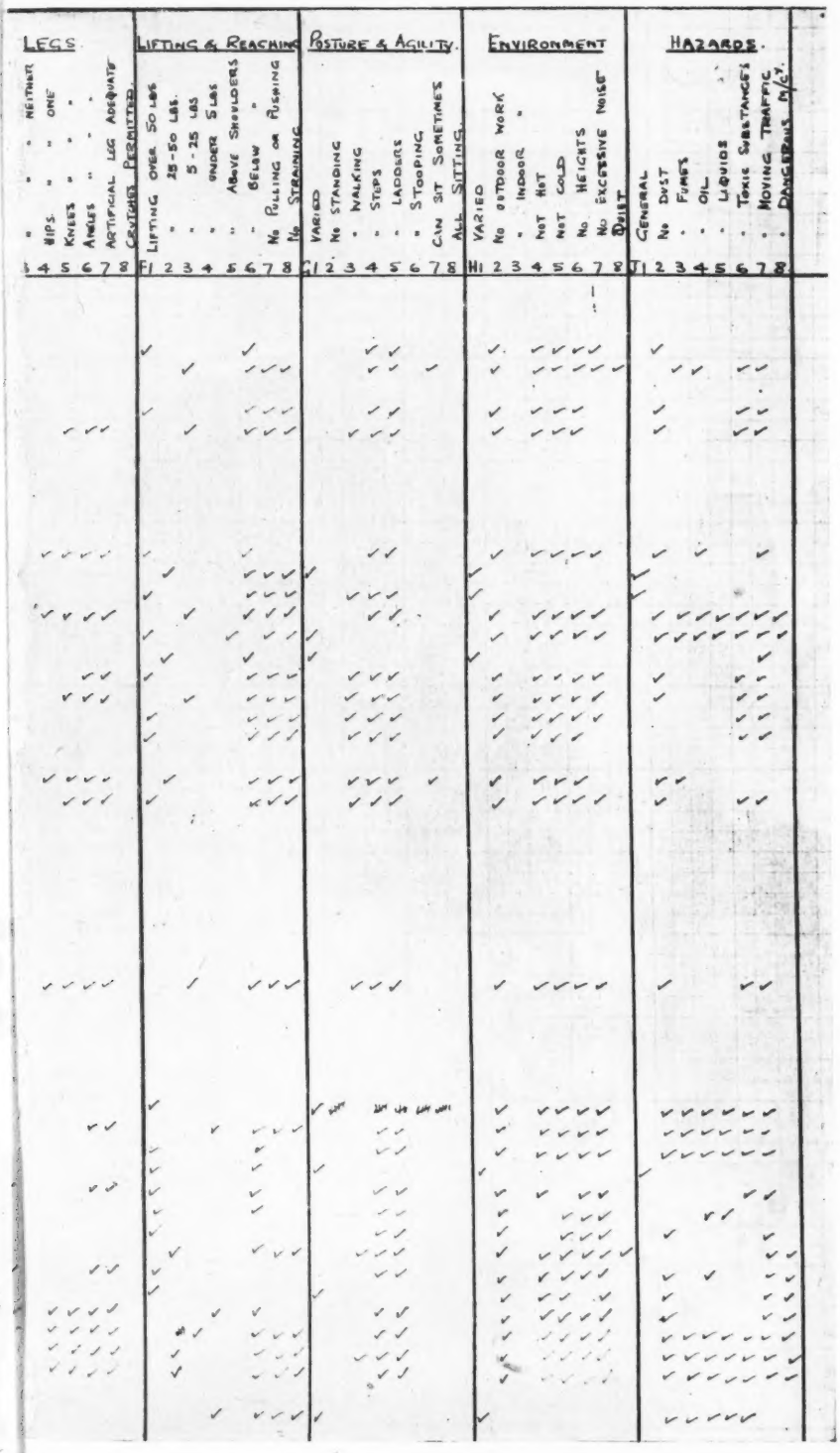

FIG. 2.—Section of a chart as described in the article; following the lines of the Hanman Master Chart, and containing the data entered on the cards, but laid out with a line to each job. The complete chart is numbered for 312 different jobs. (For notes on measurement of the various standards of ability, as described in the column headings, see Appendix, p. 106.)

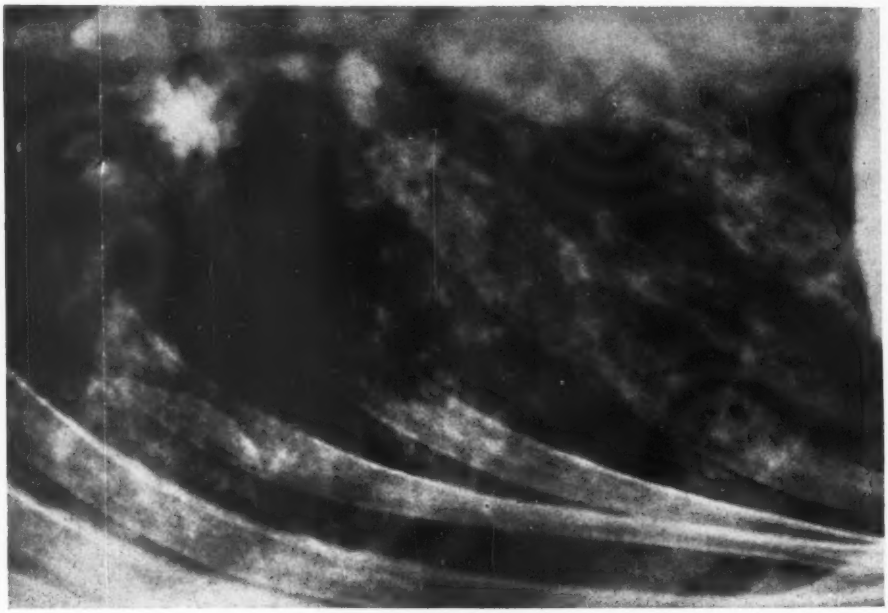

FIG. 1.—Radiograph of chest (reduced).

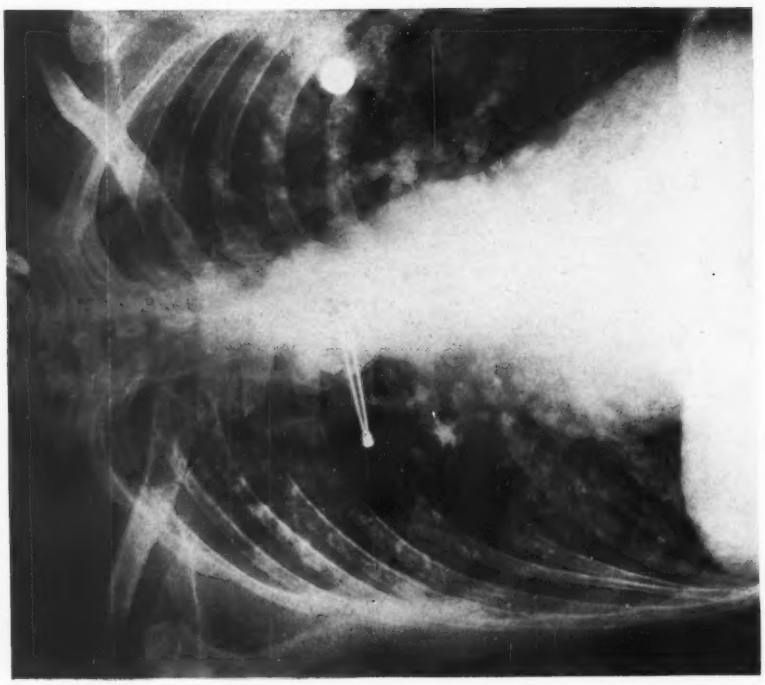

FIG. 2.—Radiograph of lung, detail (actual size).

Fig

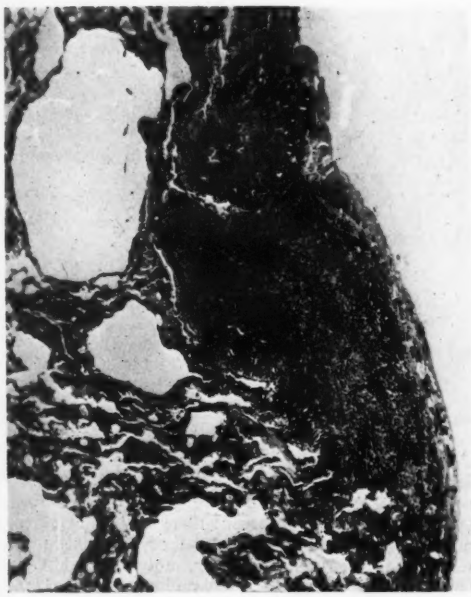

FIG. 3.—Subpleural nodule of fibrosis and underlying emphysema. Weigert's elastin stain and van Gieson. (× 29.)

FIG. 4.—Linear and circumferential fibrosis in pigmented nodule. Haematoxylin and eosin. (× 86.)

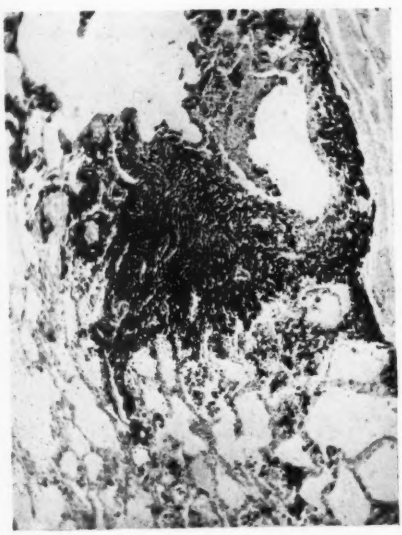

FIG. 5.—Pigmented fibrous nodule: intra-alveolar phagocytes : emphysema. Haematoxylin and eosin. (× 36.)

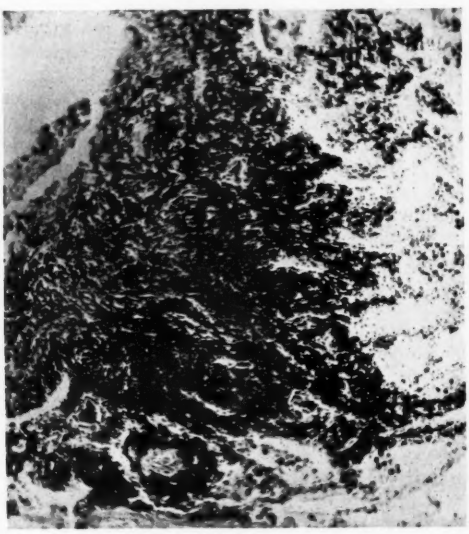

FIG. 6.—Higher magnification of fig. 5. Linear and radial fibrosis. (× 70.)

,*Brit. J. industr. Med.*, 1947, **4**, 100.

PNEUMOCONIOSIS IN A BOILER SCALER

BY

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(RECEIVED FOR PUBLICATION, OCTOBER 17, 1946)

In 1944 we reviewed the scanty literature on lung disease in boiler scalers, and gave an account of the clinical, radiological, and pathological features of the lungs of such a worker. Since then Dunner and Hermon (1944) have reported the radiographical appearances in the lungs of five boiler scalers; four of these showed reticulation, and three also had tuberculosis; the fifth was the case already recorded by us. Channell (1945) noted that dust was produced in large quantities during the cleaning of boilers, and considered that masks were essential to protect the workers. He also stated that the incidence of upper respiratory infections appeared to be higher in personnel engaged in boiler cleaning than in other naval ratings.

Cook, Kemp, and Wilson (1945) radiographed the chests of nine cleaners of Stirling and Lancashire boilers at a railway works, and found little radiological evidence of pulmonary damage. The occupational histories showed that one man was engaged on the job for twenty-five years, and the others for lesser periods down to twenty-one months; four had had long spells out of the occupation. These authors are careful to note that their report covers the conditions only as they existed at the railway works concerned, but they also state that 'while there is no doubt that boiler cleaning is an unpleasant occupation, it does not necessarily induce ill health.' Analyses of flue dust and boiler scale showed that the total silica content of the former was always higher than that of the latter, and suggested that flue cleaning is likely to be more dangerous than boiler scaling.

Case History

A boiler scaler died on Feb. 8, 1946, at the age of 44 years. He had been employed for twenty-eight years as a whole-time scaler of marine boilers, and had done no other work. He had given up boiler scaling in 1943 on account of his cough and dyspnoea.

He was taken ill acutely on Jan. 21, 1946, with cough, dyspnoea, and profuse sputum. His doctor treated him with one of the sulphonamide drugs, but his condition deteriorated and he was admitted to hospital on Feb. 4. He was thin and very cyanosed; there was slight clubbing of the fingers, and slight oedema of the ankles; his respiration rate varied (average, about 40), but his temperature was not raised. A radiograph (figs. 1 and 2) was taken on Feb. 7: it shows reticulated shadows closely distributed over most of both lung fields, the apices alone being clear. Over the lower zones, particularly on the left side, there are in addition nodular shadows, some of the nodules being sharply defined. Calcified nodes are present in the region of the right hilum. The radiological picture as a whole may be classified as one of reticulo-nodulation. Treatment in hospital included penicillin, but he died four days after admission. A post-mortem examination performed the same day showed the presence of bronchopneumonia with oedema of the lungs and pneumoconiosis. The remainder of the body showed only the effect of heart failure.

Laboratory Investigations.—After fixation, both lungs showed tags of old adhesions posteriorly, and there was a slightly general thickening of the bluish-black pleura. There was marked pigmentation of the lungs, the black pigment tending to be in small aggregates or nodules surrounded by small areas of emphysematous lung. These pigmented nodules were not clearly palpable. There was slight bronchiectasis in the right upper lobe, and ill-defined patchy pneumonic consolidation in the lower lobes. The rather large heart showed some hypertrophy of the wall of the left ventricle, and marked hypertrophy of the right ventricle, the wall of which was 10 mm. thick. There was no valvular abnormality.

Sections from the lungs showed marked black pigmentation (fig. 5) in all areas, some of it within the alveoli, some within phagocytes in the alveolar walls, and much in aggregates along the bronchi and beneath the pleura. There was no silicotic nodulation, but many of the

nodular aggregates of pigment showed collagenous proliferation (figs. 3 to 6) as well as a marked increase of reticulin fibrils. The collagenous fibrosis tended to be radial or linear rather than whorled. Most of the black pigment was apparently carbon, since it was not visible in incinerated sections, which showed a moderate amount of iron pigment but less than had been expected. Examination of incinerated and acid-treated sections with polarized light showed a dusting of silica particles throughout the nodules, but again in lesser amounts than had been anticipated.

Chemical examination of adequate samples from the whole lung showed a fairly low ash—2·55 per cent. of dry lung. Iron formed 0·40 per cent. of the dry lung (i.e. almost twice the normal maximum given by Sheldon, 1935), the total silica content was 0·20 per cent., and the free silica, determined by the method of Trostel and Wynne (1940), was 0·13 per cent. of the dry weight.

Discussion

This man had spent most of his working life as a scaler of trawler boilers, and had given up this work at the early age of 42 because of his respiratory disability. Radiography was done only shortly before his death, and some of the shadows revealed may have been due to his circulatory failure. Much of the radiological appearance was, however, the result of pneumoconiosis. His lungs show much less pathological change than those previously reported, but there is a type of nodular fibrosis which is perhaps best described as 'reticulation', although it shows more than is implied by this term. Around each pigmented nodule is an area of emphysema, a feature found to be very common in many forms of pneumoconiosis. These emphysematous areas amount in the aggregate to a large proportion of the lung, and were doubtless in large measure responsible for the patient's shortness of breath, and for the hypertrophy of the right side of his heart.

In this instance we have not analysed samples of the boiler scale from a trawler. Analysis of a sample of such scale and of flue dust was recorded in our previous paper, and showed that there was 8·6 per cent. total silica in the scale and 6·1 per cent. in the flue dust: the percentages of iron were 10·1 and 48·3 respectively. As we pointed out then, there are wide variations in analyses of scale and flue from one ship to another according to the water used in the boilers and the fuel used to fire them. In some boiler scales there is a high percentage (up to 30) of zinc, arising from the use of zinc plates in the boilers to prevent corrosion of the tubes. Channell (1945) reported a high percentage of metallic copper and small amounts of metallic oxides, notably lead, and we know of the presence of other metals. From the water will come such constituents as salts of calcium, magnesium, potassium, and sodium. In brief, the point we wish to make is that boiler scalers are exposed to the inhalation of mixed dusts which contain silica (combined and free) in varying amounts. The percentages of free silica are low compared with those usually found in the industries accepted as having a silicosis risk.

Our first case (1944) had undoubted silicosis, and the one now reported had a pneumoconiosis which did not show the classical histological appearances of silicosis. It is possible that the fibrosis found in this man's lung represented a modified or atypical form of silicosis. Experimental work (Gardner 1938; Langelez, 1946) has shown that mixed dusts containing silica may produce retarded and modified or anomalous types of fibrosis in the tissues of animals.

Summary

Some of the clinical, radiographical, and pathological features of the lungs of a boiler scaler are described. The patient suffered from increasing dyspnoea, which made it necessary for him to give up his work at the age of 42 years. He died three years later from a chest illness, one of the elements of which was a superadded bronchopneumonia. Pathological investigation showed that he had contracted a form of pneumoconiosis in which typical silicotic nodules were not found. The lesions consisted of pigmented nodules, each with a surrounding zone of emphysema, and were associated with collagenous fibrosis of linear or radial distribution, in addition to marked increase of reticulin fibrils. There was no sign of tuberculosis. The radiograph showed reticulo-nodulation.

The photomicrographs were taken by Mr. A. W. Collins, F.I.M.L.T

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For Illustrations of this Article, see pages 98 *and* 99.

Brit. J. industr. Med., 1947, **4**, 102.

THE PLACEMENT IN INDUSTRY OF THE PHYSICALLY HANDICAPPED

A PRACTICAL METHOD OF LINKING THE DISABLED PERSON WITH SUITABLE OCCUPATIONS

BY

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From Rolls-Royce, Ltd., Derby

(RECEIVED FOR PUBLICATION, OCTOBER 2, 1946)

The problem of the placing of disabled persons in industry, which was of such importance during the war years, has not disappeared on return to peace-time conditions, and the Disabled Persons (Employment) Act, 1944, turns the moral obligation of the employer into a duty. National schemes for the registration of such individuals may be designed; industry may be exhorted, cajoled, or directed to employ this or that proportion of handicapped workers; the Ministry of Labour and National Service may plan the problem centrally and through Employment Exchanges; but the ultimate success of the idea and its practical fulfilment will finally depend on the willing co-operation of each individual industry, of each individual firm, and of each individual labour bureau in that firm.

Great efforts were made under the stress of war to absorb disabled persons into the war production army, and the methods of placing those so handicapped have varied from simple to elaborate schemes. These methods are still in the stage of evolution, and, in our search for the ideal plan, schemes are being developed in some industrial units which have long since been discarded by others as too time-consuming or otherwise impractical. A pooling of knowledge and experience is necessary.

In general the problem has hitherto been dealt with by one of three methods. The most primitive may be called the 'trial and error' method. A man is tried on a job, and if he is found incapable he may be tried on another, and so on until he is marked unemployable as far as the factory is concerned. In the 'personal memory' method, the labour manager carries in his head a list of jobs which are suitable for various disabilities; one-armed men, one-legged men, and so on. A labour manager of experience may, indeed, have a very complete picture of such jobs in his mind, but dependence on individual memory has the great disadvantage that when the labour manager leaves, or is away temporarily, his memory is no longer available; the department is thus at a loss, and the company he serves thereby suffers. The third method may be called the 'disability list' method. The labour manager's memory is replaced by lists of jobs which can be done by workers with certain disabilities. This is an advance on the first two methods, but usually results in lists containing a few 'odd-lot' jobs of a dead-end variety, including such jobs as lavatory attendant, weighbridge keeper, or night watchman.

The method here described may be called the "job analysis" method. It has been developed during the recent war, particularly in the British Army and in the United States of America.

Job Analysis

I believe it to be essential for the proper absorption and utilization of disabled persons that there should be an ordered scheme of analysis of jobs which will indicate the physical characteristics that each job demands from its operator. Many such schemes have been designed, some simple, some intricate. One of the simpler is the Pulhems system, which is used in the British Army and elsewhere. Jobs and men are assessed in seven main characteristics (the initials of which give the name to the system—physique, upper limb, locomotion, hearing, eyesight, mental ability, and stability (emotional). Some other methods are most elaborate and complicated. Most of them 'work,' but this is not enough. The successful system is one which not only works but is in fact used. Many industrial medical officers and personnel managers are concerned with this problem, and some have evolved their own particular way of tackling the matter, the object of which is to match the man to the job to the mutual advantage of the man and the industry.

This paper presents a scheme which is more eleborate than that used in the Services, the Pulhems system appearing inadequate for modern industrial purposes. It is not so elaborate as some American

schemes, which appear too complicated for practical everyday use, but which nevertheless have been found to be helpful in certain respects. The best of each has been used to make up the scheme now presented, which is not put forward with any claim to originality, but is rather the result of an abstraction in the light of my own experience of what has appeared to be useful in a number of schemes.

A form was designed for recording the minimum physical requirements of each job. It will be seen that the form (see legend to fig. 1) lists nine groups of physical characteristics, environmental conditions, and hazards, with usually eight subdivisions in each group; after each sub-division there is a small ruled-off square. This form is used in the first step in job analysis, and a tick is placed in the small square corresponding to that degree of physical capacity which represents the minimal requirement for the job, or which indicates the demand on physical effort, postural ability, etc., or, in the case of hazards, the absence of hazards which might prevent a particular man from undertaking the job. While there may be an inclination to record other physical attributes on this form—and in some industries they may be called for—a warning is given against over-elaboration, leading to unwieldiness, which will defeat the object of the system, namely, rapid job placement. However, each group has a spare line, and there are three spare groups, at K 1–9, L 1–9, and M 1–9 for future additional entries should these become necessary.

It should perhaps be stressed that the completion of this form should not be a matter of guess-work, or of probabilities, or of vague knowledge. It is not a fireside occupation. It will be found in practice that the only satisfactory way of completing the required details is the three-step method of (1) seeing the job done, (2) talking to the man who does it, and (3) talking to the superintendent of the department where the job is done. It will soon be found that the word 'job' conveys a meaning which is different from that usually understood in the labour bureau, and that many jobs on the Labour Code represent a number of varieties of work which cannot be satisfactorily analysed except by subdividing the main job into a number of sub-headings. The job of labourer is perhaps as good an example as any; there are general labourers, stores labourers, millwrights' labourers, laboratory labourers, etc., whose jobs each differ from each other in their physical requirements.

Although the assessment of jobs in this manner is not one which is necessarily best done by the industrial medical officer, he should, nevertheless, give help concerning the standards to be used. Indeed, co-operation is essential, for it is important that the assessor and the medical officer should talk the same language. The meaning of good, medium, etc., as applied to vision must be clearly understood; a number of headings, necessarily brief on the form, require explanation or elaboration. I have attached my own personal meanings to these headings and shall refer to them at the end of the paper. It is sufficient to say that the co-operation between medical officer, assessor, and personnel manager should be such that when the medical officer gives his opinion that an employee is fit to work with certain limitations, he can be confident that, guided by the assessor's analysis, the right kind of job will be found. For this reason it may be as well that medical officers should have a considerable hand in analysis, or at least in the training of assessors. Analysis actually undertaken by the medical officer will be invaluable to him, though pressure of work may make it difficult.

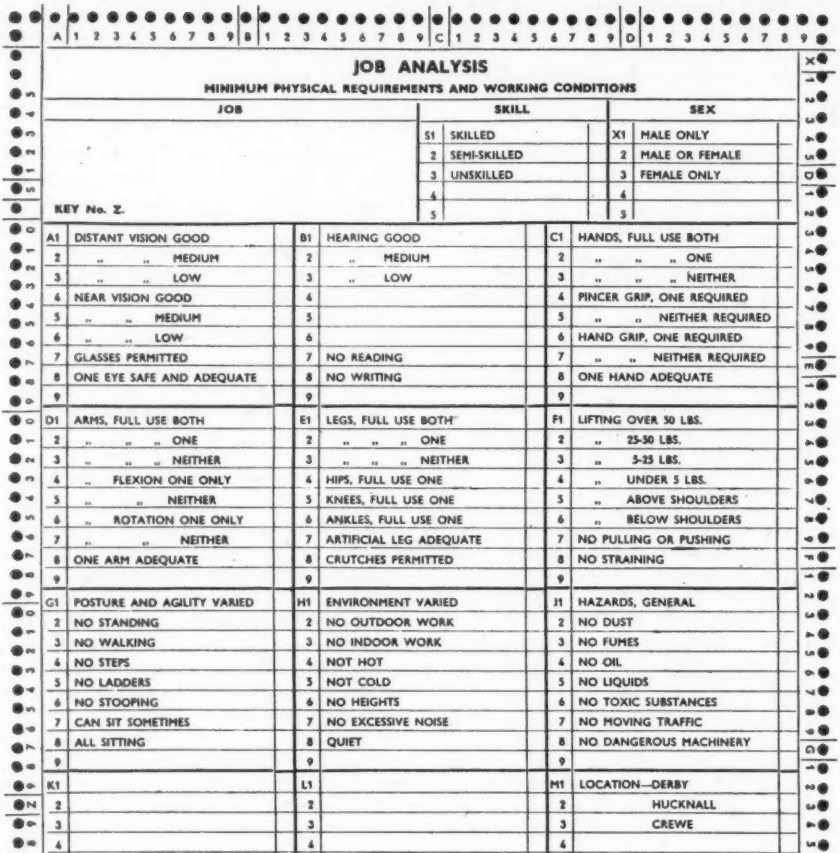
It is important that the analysis should be agreed on by the superintendent of the department where the job is located, since he may in the future be asked to employ a man with a disability and his co-operation will be essential. His prior agreement is obviously of great value. It is also important that the medical officer, in his pre-employment medical examination, should think along the lines of this analysis and express his conclusions in such a way that they conform to the information available on the analysis sheets. Physical diseases and deformities must be translated into abilities and disabilities as shown on the form (fig. 1).

Matching the Man and the Job

The next part of the problem is to match the disabled person with the suitable job. Is there a rapid, simple, and practical method by which jobs within the capacity of handicapped men can be brought up for consideration? The scheme must indicate jobs which are within the capacity of individuals with various combinations of handicaps, and it must enable the personnel manager to say with confidence whether or not a suitable job is available for a particular case.

After consideration of a number of mechanical and other methods of sorting, it was decided to put the information obtained from the job analysis on to cards (The Paramount Card, obtainable from Copeland-Chatterson Co., Ltd., Stroud, Gloucestershire). These cards have holes punched round the edges at the top and bottom and both sides; a hole can be converted into a 'V' with a simple instrument; each hole can be labelled to correspond with a particular item of information, and is to be cut into a 'V' when that information applies. When the cards are properly aligned, and a finder passed through a particular hole and raised, intact cards will be lifted up while those in which the hole has been cut into a 'V' fall out. Such a card has been designed for the present purpose, the information being recorded as on the analysis sheet. Holes have been allotted to each physical demand, and, where a particular characteristic is ticked as being applicable, the corresponding hole is converted into a 'V.'

When an applicant for work is found on medical examination to have a disability which limits the full range of normal activities in any way, the possible jobs which it would be wise and safe for him to undertake can quickly be found by inserting the finder in the appro-



JOB ANALYSIS

MINIMUM PHYSICAL REQUIREMENTS AND WORKING CONDITIONS

JOB	SKILL		SEX	
	S1	SKILLED	X1	MALE ONLY
	2	SEMI-SKILLED	2	MALE OR FEMALE
	3	UNSKILLED	3	FEMALE ONLY
	4		4	
KEY No. Z.	5		5	

	A1	B1	C1
1	DISTANT VISION GOOD	HEARING GOOD	HANDS, FULL USE BOTH
2	" " MEDIUM	" MEDIUM	" " " ONE
3	" " LOW	" LOW	" " " NEITHER
4	NEAR VISION GOOD		PINCER GRIP, ONE REQUIRED
5	" " MEDIUM		" " NEITHER REQUIRED
6	" " LOW		HAND GRIP, ONE REQUIRED
7	GLASSES PERMITTED	NO READING	" " NEITHER REQUIRED
8	ONE EYE SAFE AND ADEQUATE	NO WRITING	ONE HAND ADEQUATE
9			

	D1	E1	F1
1	ARMS, FULL USE BOTH	LEGS, FULL USE BOTH	LIFTING OVER 50 LBS.
2	" " " ONE	" " " ONE	" 25-50 LBS.
3	" " " NEITHER	" " " NEITHER	" 5-25 LBS.
4	" FLEXION ONE ONLY	HIPS, FULL USE ONE	" UNDER 5 LBS.
5	" " NEITHER	KNEES, FULL USE ONE	" ABOVE SHOULDERS
6	" ROTATION ONE ONLY	ANKLES, FULL USE ONE	" BELOW SHOULDERS
7	" " NEITHER	ARTIFICIAL LEG ADEQUATE	NO PULLING OR PUSHING
8	ONE ARM ADEQUATE	CRUTCHES PERMITTED	NO STRAINING
9			

	G1	H1	J1
1	POSTURE AND AGILITY VARIED	ENVIRONMENT VARIED	HAZARDS, GENERAL
2	NO STANDING	NO OUTDOOR WORK	NO DUST
3	NO WALKING	NO INDOOR WORK	NO FUMES
4	NO STEPS	NOT HOT	NO OIL
5	NO LADDERS	NOT COLD	NO LIQUIDS
6	NO STOOPING	NO HEIGHTS	NO TOXIC SUBSTANCES
7	CAN SIT SOMETIMES	NO EXCESSIVE NOISE	NO MOVING TRAFFIC
8	ALL SITTING	QUIET	NO DANGEROUS MACHINERY
9			

	K1	L1	M1
1			LOCATION—DERBY
2			HUCKNALL
3			CREWE
4			
5			
6			
7			
8			
9			

SPECIAL REMARKS

ANALYSED BY

FIG. 1.—Card for recording minimum physical requirements of particular jobs. The form spoken of at p. 103 is made out exactly like the card, except that the punched holes with their corresponding letters and numbers are absent. (For notes on the standards used, and the interpretation of headings on this card, see Appendix, p. 106.)

(NOTE.—Section D had two sets of punched holes erroneously printed for it. This is a mistake that will be remedied in future printings.)

priate hole and raising the cards on the finder; those cards relating to jobs to which that particular disability is no bar will fall out and plainly bring to notice all the jobs within his physical capacity. In cases where two disabilities or limitations apply, the finder will be passed through twice, or, alternatively, two finders may be used simultaneously. It does not matter in what order the cards are assembled, and it is not necessary to put them back in order.

The choice of suitable employment is limited by the matter of skill, a number of jobs being reserved for skilled men. It would be a waste of time for the labour bureau to search through skilled jobs where the applicant is unskilled, and the cards have, therefore, been marked according to whether the job is skilled, semi-skilled, or unskilled, and appropriate holes allotted. In practice, the labour bureau will keep its cards in several 'packs,' separating the skilled from the other jobs, the male from the female, etc.

For the industrial medical officer who is not wholly familiar with all the varying occupations in the factories with which he is concerned, the cards will prove of value when a man is referred for an opinion as to fitness for a particular job. By referring to the appropriate job analysis card the medical officer can learn quickly the various physical attributes which are essential and those which are unnecessary. In order to find a particular card, the cards have been numbered and thirty holes set aside, numbering 0 to 9 three times, thus making it possible to find with ease a card with any number from 0 to 999.

In some circumstances the indication of the 'location' of the job will be helpful, particularly where there are a number of separate factories with a central labour bureau. It is not uncommon to find that a job called by a particular name in one factory requires different characteristics from that called by the same name in another factory, even within the same organization. An obvious example is where one factory is built entirely on ground level and another on two or more floors. In the latter some occupations may require the use of steps, which are non-existent in the former. It may, therefore, be as well to prepare two cards, identical except for the reference to 'steps' and to 'location.'

For some purposes it is more useful to have the information given on the cards available in the form of a chart. The idea of the chart was given to me, in a personal communication, by Mr. Hanman, Chief of the Physical Demands and Incapacities Analysis Section of the District Civilian Personnel Office, Twelfth Naval District, San Francisco, whose contribution is full of much thought and constructive criticism. The chart illustrated in fig. 2, pp. 96-97, following the lines of the Hanman Master Chart, contains the data to be found on the cards, but is laid out with a line to each job. The value of the chart lies chiefly in providing quick reference to the characteristics required by a particular job, thus saving the abstraction of the particular card from the pack. The Hanman chart is, however, used for more than this. It can take the place of the perforated cards here described in direct matching up of man to job. Nevertheless, for the purpose of discovering quickly all suitable jobs for a particular disabled man, I believe that the Paramount card is more suitable and more likely to be used.

Summary

A scheme is described by which a disabled man can be matched to a job. There are both limitations and disadvantages in the scheme, which is regarded as being in the experimental stage. It covers only a few of the problems demanding attention and which call for more investigation. A valuable contribution will be made to the solution of the problems of the Ministry of Labour and National Service if combined information on these lines from many sources and from large numbers and varieties of industries is made available.

The investigation represents field work which must be done at the periphery, but the results should be centralized and made available to others so that ground covered need not be covered again.

A plea is put forward for the extensive use of job analysis, from the point of view of the physical demands made by each job, as a necessary preliminary to the satisfactory absorption in industry of the physically handicapped individual.

A practical method of recording these demands, physical and environmental, is described.

A new method is described of linking the disabled individual with the job shown to be suitable by analysis.

I am indebted to a number of individuals who have helped me in this problem. In particular I would mention Dr. R. S. F. Schilling, Secretary of the Industrial Health Research Board of the Medical Research Council, Mr. Bert Hanman, War Manpower Commission, San Francisco, Mr. H. C. Weston, Senior Investigator, The Industrial Health Research Board, and Mrs. Bridget Bramwell, late of the American Library, The U.S. Office of War Information, The American Embassy, London. My thanks are due also to a large number of the Staff and Employees of Rolls-Royce, Ltd., who have assisted me in analysing jobs or have supplied constructive criticism, and to Mr. T. S. Haldenby, General Manager, Rolls-Royce, Ltd., for encouragement in this work and for permission to publish this article. The list of references gives the books, articles, and pamphlets that have been consulted and that have contributed to the final scheme.

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APPENDIX

NOTES ON THE STANDARDS USED AND THE INTERPRETATION OF OTHER HEADINGS ON JOB ANALYSIS SHEETS AND CARDS

In using the analysis sheets and cards, the following standards and interpretations were understood, so that there should be adequate co-operation between medical officers and personnel managers. It was necessary to have these clearly determined since there are no agreed standards in common use in industry.

Vision

Distant vision good:
Ability to read with each eye separately the sixth line of the Snellen test type card at a distance of twenty feet. (V.A. 6/9 6/9 or better.)

Distant vision medium:
Ability to read the fourth line of the Snellen test type card at twenty feet with each eye separately. (V.A. 6/12 to 6/18.) This standard is the minimum allowed for drivers of motor vehicles on the public highway.

Distant vision low:
Less than the above standards.

Near vision good:
Ability to read with each eye separately at a distance of thirteen inches the Jaeger test types Nos. 1 or 2.

Near vision medium:
Ability to read as above Jaeger test types Nos. 3 to 6.

Near vision low:
Less than the above.

In assessing the job the degree of vision required will depend on the two factors of safety and adequacy. Very few factory jobs require distant vision of any kind for the actual performance of the job, but there are a number which are done under circumstances carrying a risk of injury from moving traffic, overhead cranes, etc., calling for sudden avoiding movement. Such jobs, from the safety aspect, will call for medium distant vision.

When the vision of one eye is in the 'low' category, the individual should for job placement purposes be classed as one-eyed in the category of the better eye, and should be employed only on work where it is considered that one eye is safe and adequate.

Hearing

Hearing good:
Ability to hear whispered speech at ten feet with each ear separately.

Hearing medium:
Ability to hear conversational speech at ten feet, with both ears together.

Hearing low:
Less than the above.

Use of Limbs

Full use of hands, arms, and legs:
From the assessor's point of view this means exactly what it says. From the medical officer's point of view it is important that function is considered rather than anatomical perfection. Many a workman with a missing forefinger finds this no handicap whatever.

Lifting:
This refers to lifting without help. The medical officer will consider under this heading the state of the man's hands, arms, and back, and the condition of his heart, presence of a rupture, etc.

Environment

Heat and cold:
Temperatures over 80° F. are to be considered hot; those below 55° are to be considered cold.

Heights:
Apart from work on roofs and ladders, there are a few jobs where a man stands on a platform. The criterion here is whether a slip or fall is likely to cause more injury than a slip or fall when standing on ground level. From the medical aspect a liability to giddiness would call for a job with 'no heights'.

Loud noise:
This means something more than the average shop noise—for example, the noise of test-beds, tinsmiths, drop forge, or pneumatic drills.

Quiet:
This refers to jobs of the degree of quietness of an office.

Hazards

Dust fumes:
This means no more than the average factory dust or fumes, which are, in fact, very little. Most jobs fall into this category.

Oil:
This has particular reference to the risk of oil dermatitis, and, therefore, not only contact with cutting oils on machines, but the handling of oily components would be excluded here.

Toxic substances:
This refers to all those substances which may have an ill-effect on health on reaching the interior of the body, whether absorbed through the gastro-intestinal tract, the lungs, or the skin. It does not include substance liable to cause dermatitis or ulceration of the skin.

Dangerous machinery:
All machine tools are potentially dangerous. In addition this heading can conveniently be used to include other dangers, such as pits, tanks, etc., into which a man might fall. This heading refers to stationary machinery.

Moving traffic:
Not only power-driven trucks and other vehicles are referred to here; there are also included overhead cranes and other hazards which might call for sudden avoiding movement. The medical officer will consider visual acuity and hearing and also the workman's agility on his legs. Workmen with artificial legs will be better away from such risks.

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A STUDY OF REPETITION OF ACCIDENTS

BY

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Detailed records of all accidents reported at the surgery were kept in a small Royal Ordnance Factory (Engineering), from July 1, 1945, until November, 1945, by which time the factory had almost closed down. Seven 'Centres' showed a sufficient number of accidents to warrant subdivision. These were:

Centre A	Shell turnery	Centre D	Heavy turnery
Centre B	Shell turnery	Centre E	Tool room
Centre C	Machine tool setters	Centre F	Inspection
		Centre G	Maintenance

Three major classifications of accidents were adopted: (1) 'what the injured person was doing at the time of the accident' (referred to subsequently as 'operation'); (2) body site of injury (location); (3) nature of injury. Classifications (1) and (2) were devised for this investigation; classification (3) is the International Labour Office classification, which was already in use in the factory.

Data

Table 1 shows the distribution of accidents in each centre. As these records are from the end of the war period, with the factory closing down, individuals cannot be assumed to have had equal exposure to accident hazard, and, therefore, any test against a Poisson distribution is not possible. It is, therefore, impossible to decide whether any individuals could be called 'accident prone.'* Another relationship is studied. Let us suppose, as a simple case, that a group of people engaged on the same work sustained twenty accidents, and that these were distributed according to a classification of accident type:

TABLE 1
FREQUENCY DISTRIBUTION OF ACCIDENTS TO INDIVIDUALS

No. of persons with	Centres							Total
	A	B	C	D	E	F	G	
1 accident	68	41	17	29	11	22	19	207
2 accidents	14	18	2	15	9	4	10	72
3 accidents	2	3	2	6	2	0	0	15
4 accidents	2	1	1	3	0	0	3	10
8 accidents				1				1
No. of accidents ..	110	90	31	97	35	30	51	444

Type	Frequency
A	10
B	6
C	4

Two of these occurred to one individual, and we wish to know the chance that they are of the same type. Altogether there are 190 pairs of accidents ($20 \times 19 \times \frac{1}{2}$). Of these, 45 pairs are both type A ($10 \times 9 \times \frac{1}{2}$), 15 pairs both type B, and 6 pairs both type C; giving the probability of any pair being of the same type as $\frac{66}{190}$. Thus, Centre E, with 35 accidents, has 595 pairs of accidents. Three accidents are of the nature 'bruises, contusions, abrasions' (Table 5), and, therefore, three of the 595 pairs have both accidents of this nature. Altogether

Nature	No. of accidents	No. of pairs
Bruises, etc. ..	3	3
Burns and scalds ..	2	1
Cuts and lacerations	20	190
Punctures	3	3
Sprains and strains	2	1
Eye injuries ..	5	10
	35	208

The probability of two accidents being of the same nature in this centre is, therefore, $\frac{208}{595} = 0{\cdot}3496$.

Table 1 shows that in this centre, eleven individuals each have one accident, nine have two accidents, and two have three accidents. Thus the total number of pairs of accidents by the same individual is 15. Therefore $15 \times 0{\cdot}3496$ is the expectation of pairs of accidents of the same nature happening to the same individual. This is 5·24.

Expected frequencies were obtained in this way centre by centre for operation, nature, and location classifications. As these classifications are not independent, i.e. accidents occurring in particular operations most often produce injury to a particular

* E. Farmer and E. G. Chambers. *Industrial Health Research Board*. Reports Nos. 38, 55, and 68; M. Greenwood and H. M. Woods, *Ibid.*, Report No. 4.

part of the body, etc., the expected frequencies of same location + same operation and the other multiple classifications, were all calculated separately in this manner.

'Unknown' categories are a troublesome complication, but it was decided to distribute the unknowns in accordance with the distribution of the known accidents. As there are relatively few, any error introduced will be small.

TABLE 2

OBSERVED AND EXPECTED DISTRIBUTIONS (ACCORDING TO FOUR HYPOTHESES) OF ACCIDENTS SUSTAINED BY INDIVIDUALS WHO HAVE HAD MORE THAN ONE ACCIDENT DURING PERIOD

Category	Observed no. of pairs	E.1	E.2 *O* kept constant	E.3 *L* kept constant	E.4 *N* kept constant
O	87·1	53·49	(87·1)	56·88	56·91
w	117·9	151·51	(117·9)	148·12	148·09
X^2		28·57		22·22	22·17
d.f.		1		1	1
Probability		<·0001		<·0001	<·0001
L	111·3	88·04	93·28	(111·3)	96·40
l	93·7	116·96	111·72	(93·7)	108·60
X^2		10·77	6·39		4·35
d.f.		1	1		1
Probability		<·0001	*c.* ·012		*c.* ·037
N	88·1	63·48	67·27	71·45	(88·1)
n	116·9	141·52	137·73	133·55	(116·9)
X^2		13·82	9·60	5·96	
d.f.		1	1	1	
Probability		>·0001 <·001	<·002	*c.* ·015	
OL	53·09	26·09	41·54	34·64	29·28
Ol	34·01	27·40	45·56	22·24	27·63
wL	58·21	61·95	51·74	76·66	67·12
wl	56·69	89·56	66·16	71·46	80·97
X^2		41·83	7·58	22·38	27·61
d.f.		3	2	2	3
Probability		<·0001	*c.* ·022	<·0001	<·0001
ON	43·50	18·11	28·44	21·28	25·63
On	43·60	35·38	58·66	35·60	31·28
wN	44·60	45·37	38·83	50·17	62·47
wn	73·30	106·14	79·07	97·95	85·62
X^2		47·68	13·12	31·82	24·20
d.f.		3	2	3	2
Probability		<·0001	*c.* ·0014	<·0001	<·0001
LN	71·53	40·30	45·64	54·02	54·86
Ln	39·77	47·74	47·64	57·28	41·54
lN	16·57	23·18	21·63	17·43	33·24
ln	77·13	93·78	90·09	76·27	75·36
X^2		30·37	19·03	11·08	13·54
d.f.		3	3	2	2
Probability		>·0001 <·001	<·0001	*c.* ·004	*c.* ·0013
OLN	36·92	12·85	30·17	17·53	16·72
OLn	16·71	13·24	21·37	17·11	12·56
OlN	6·58	5·26	8·27	3·75	8·91
Oln	27·43	22·14	37·29	18·49	18·72
wLN	34·61	27·45	25·47	36·49	38·14
wLn	23·60	34·50	26·27	40·17	28·98
wlN	9·99	17·92	13·36	13·68	24·33
wln	49·70	71·64	52·80	57·78	56·64
X^2		62·87	22·71	37·02	40·73
d.f.		7	6	6	6
Probability		<·0001	*c.* ·001	<·0001	<·0001

O = same operation in both accidents of pair.
L = same location of injury in both accidents of pair.
N = same nature of injury in both accidents of pair.
OL = same operation + same location, etc.
w = different operation.
l = different location.
n = different nature.

The process described above gives Expectation 1, which is shown, summed for all centres in Table 2. χ^2 tests of goodness of fit show that it disagrees markedly with the observed data, and indicates that the individuals concerned had accidents of the same type much more often than would be expected from the distribution of accidents in each centre. Three simple hypotheses to explain this are possible, and must be considered. They are: (1) individuals tend to repeat their accidents on the same operation; (2) they tend to repeat an injury to the same part of the body; (3) they repeat the same nature of injury.

In order to test the validity of these hypotheses, three further sets of expected frequencies were calculated. These were: (1) given, in each centre, the operations of the accidents in each pair studied; what frequencies would we expect (based on the distribution in the centre) of pairs with the same location, with the same nature, or with the same nature + same location (distribution E.2 shown summed for all centres in Table 2); (2) similarly, but given the location of the accidents studied (distribution E.3, Table 2); (3) similarly, but given the nature of injury (distribution E.4, Table 2).

Calculation of E.2 involved working out the probability of the same location occurring in two accidents, one of operation 1, the other operation 2, etc., from the overall data in each centre. Tables of these probabilities for all combinations of operation categories were prepared, and by inspection of the operations in the pairs studied the expected frequencies in each category were obtained. The summation of these for all centres is given in Table 2. Distributions E.3 and E.4 were calculated in similar fashion.

TABLE 3

FREQUENCY DISTRIBUTION OF ACCIDENTS IN OPERATION CATEGORIES

(Classification 1)

Operation	Centre							Total
	A	B	C	D	E	F	G	
Placing product in, or taking it out of power machine	32	24	9	24	0	3	0	92
Operating or setting power machine, other than above	23	21	11	33	13	4	8	113
Using hand machine or tool	8	13	1	9	12	0	27	70
Handling material, other than in machine or tool operating	30	27	4	15	8	18	9	111
Walking about or carrying objects inside shop	11	3	5	15	1	4	2	41
Walking about or carrying objects outside shop	1	1	0	0	0	0	0	2
Driving lorries, vans, etc.	0	0	0	0	0	0	0	0
Cleaning and sweeping	2	0	0	0	0	0	0	2
Unknown	3	1	1	1	1	1	5	13
Totals	110	90	31	97	35	30	51	444

TABLE 4

FREQUENCY DISTRIBUTION OF ACCIDENTS IN LOCATION OF INJURY CATEGORIES

(Classification 2)

Location	Centre							Total
	A	B	C	D	E	F	G	
Head and face (not eyes)	0	0	1	8	3	0	3	15
Neck	4	0	0	0	0	0	0	4
Back	1	1	0	2	0	0	1	5
Chest	0	0	0	1	0	0	0	1
Abdomen	0	0	0	0	0	0	0	0
Pelvis *	0	0	0	0	0	0	0	0
Eyes	7	7	1	15	5	2	5	42
Shoulder and upper arm	0	0	0	1	0	0	0	1
Elbow	1	1	1	1	0	0	1	5
Forearms	8	3	3	5	0	0	1	20
Wrist, hand, and fingers	67	62	22	57	24	18	32	282
Thigh †	0	0	0	1	0	0	0	1
Knee	0	1	0	2	2	1	0	6
Lower leg	8	2	1	3	1	2	1	18
Ankle	9	5	1	0	0	1	1	17
Foot	4	7	1	1	0	6	1	20
Unknown	1	1	0	0	0	0	5	7
Total	110	90	31	97	35	30	51	444

* Including perineum and buttocks for superficial injuries.
† Including all femur fractures and superficial injuries to hip.

TABLE 5

FREQUENCY DISTRIBUTION OF ACCIDENTS IN NATURE OF INJURY CATEGORIES

(Classification 3)

Nature of injury	Centre							Total
	A	B	C	D	E	F	G	
Bruises, contusions, abrasions	23	20	7	13	3	5	11	82
Burns and scalds ..	12	8	0	9	2	4	1	36
Concussions	0	0	0	1	0	0	0	1
Cut and lacerations ..	37	33	14	57	20	10	22	193
Punctures	14	19	2	3	3	6	6	53
Amputations, traumatic	0	0	0	0	0	0	0	0
Dislocations	0	0	0	0	0	0	0	0
Fractures	0	0	0	0	0	0	0	0
Sprains and strains ..	7	4	7	2	2	3	1	26
Asphyxiation	0	0	0	0	0	0	0	0
Drowning	0	0	0	0	0	0	0	0
Eye injuries	6	5	1	12	5	2	5	36*
Gas effects	0	0	0	0	0	0	0	0
All other	1	0	0	0	0	0	0	1
Unknown	10	1	0	0	0	0	5	16
Total	110	90	31	97	35	30	51	444

* The discrepancy between 'Eye Injuries' in Table 5 and 'Eyes' in Table 4 is caused by five of the latter appearing as 'burns and scalds' in Table 5 and one as 'cuts and lacerations,' and exemplifies the disadvantages of Classification 3 (I.L.O. classification), as its categories are not exclusive and attempt in this case to mix 'nature' and 'location' classifications.

χ^2 tests of goodness of fit were applied (with one fewer degrees of freedom where the constants introduced are directly effective), but none of the distributions is a satisfactory fit of the observed data, although all are better than E.1 Distribution. E.2 (operation constrained) is the nearest fit of the three.

Discussion

The first point which is established is that individuals who have two or more accidents more often have the same kind of accident than would be expected from the risks of their work. The other theoretical distributions tried mean, in practice, the following:

E.2. *Operation constrained.*—If this distribution fitted the observed data, it would indicate that an individual has higher liability to accident at certain operations in his work, but not necessarily to the same operation as other individuals engaged on the same work. It is possible that this would be the result of highly individual variation in the movements required in that operation, and that the individual was—in effect—clumsy at one particular operation.

E.3. *Location constrained.*—This would imply that some individuals nearly always injured their feet, whereas others injured their hands, etc.

E.4. *Nature constrained.*—At first sight there seems little *a priori* ground for considering this hypothesis, but it is possible that there is variation in willingness to report injuries of different natures, i.e. some individuals might always report cuts but neglect burns, whereas others might do exactly the opposite.

None of the distributions, however, fit the observations to any satisfactory degree, but distribution E.2 (operation constrained) is the best of the three. The only conclusion which can be drawn at this stage is that this is one factor causing similarity in an individual's accidents, but not the only one. Further data on more individuals with longer exposure to accident is required for study of a hypothesis combining these factors, and it seems likely that this will show all three factors relevant in varying degree.

It must also be borne in mind that, although the observations were treated centre by centre—that is, in units as homogeneous in risk as it was possible to obtain—the homogeneity is by no means perfect. Machines vary somewhat in each centre, and cause variation in the exact nature of the operation performed. But it is unlikely that this external variation will account for the whole of the findings. Further work will, however, require a more rigorous subdivision into units homogeneous in external risk, before complete satisfaction can be obtained on this point.

It should be possible in this way to determine the extent to which an individual's specific liabilities contribute to the accident rate of varying occupations. It should further be possible, by inspection

of surgery records, to define a given individual's specific liability, and, by observation of his movements in this specific hazard, to suggest the particular retraining required to eliminate the hazard.

Summary

In a number of occupations at a Royal Ordnance Factory (Engineering), the accidents of individuals who have sustained two or more accidents are studied. The following conclusions are reached:

1. That individuals who have more than one accident are more likely to have accidents of the same type (as regards what they were doing at the time of the accident, as regards the body site of injury, and as regards the nature of injury) than is to be expected from the risks of their occupation.
2. Three hypotheses to account for this are studied: (*a*) that they tend primarily to have accidents at the same operation in their work, (*b*) that they tend primarily to injure the same part of themselves, (*c*) that they tend primarily to have the same nature of injury. None of the above hypotheses fits the data to a satisfactory degree, but (*a*) is the best of the three. Further work on a larger scale is suggested, so that combinations of the hypotheses may be tried.
3. An indication is given of possible practical applications.

The writers are indebted to Dr. A. J. Amor, Chief Medical Officer of the Ministry of Supply, for facilities for carrying out this investigation, and to Mr. W. McKinlay, Labour Officer, and others of the staff at the factory concerned, for their assistance in the investigation.

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HEALTH HAZARDS OF THE PHARMACEUTICAL INDUSTRY

BY

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In recent years the pharmaceutical industry has come to occupy a unique position in regard to problems of industrial hygiene and toxicology ; practically no other single commercial enterprise presents such a wide variety of potentially toxic exposures or such a rapidly-changing advent of new chemical substances. This dynamic situation, which renders the work of the plant physician so instructive in this industry, has been created by the increasing application of organic chemical synthesis as a method for producing therapeutic substances. Around the core of the old industry, which was chiefly concerned with extracting active ingredients from medicinal herbs, there has been built up in the past twenty years a new and highly-complicated fine chemical manufacturing enterprise, concerned with intricate organic syntheses, and dependent for its life on being able to follow the most advanced techniques developed in the research laboratory. Such manufacture, which seldom settles down to the sober mass-production of the heavy chemical industry, is essentially a batch-process and half-experimental business, full of unexpected occurrences, strange chemical substances, and unusual toxicological problems. It is rarely able to make use of manufacturing equipment specifically designed for one synthesis; that is a privilege reserved for heavy chemicals. As a consequence, more versatile equipment must be used—equipment which must always fall short of the ideal in either safety or efficiency where any specific synthesis is concerned.

This concretion of the new industry around the old makes a convenient division in the consideration of toxicological hazards: the problem of handling crude vegetable drugs and their extracts may be considered separately from the more complicated problems of synthetic chemistry in the factory. Under a third heading certain miscellaneous hazards to health will be considered.

Hazards from Handling Crude Drugs and Their Extracts

The hazards of extracting active principles from crude drugs are unequally divided between the three classes of materials involved; the herbs themselves, the solvents, and the finished active material. Of the three, the crude materials offer the least striking dangers to health. Two exceptions which have been prominent in my own experience are ipecacuanha and podophyllum.

Ipecacuanha.—The powdered form of the former may act as a mild primary irritant on the skin and mucous membranes, but is especially dangerous to those who have developed an allergic sensitivity to it; asthma specifically caused by this herb has been described (Salter, 1860; Peshkin, 1920). I have seen one nearly fatal asthmatic seizure provoked by inhalation of very small amounts of dust from the powdered drug.

Podophyllum.—Podophyllum root is still handled in large amounts as a source of the benzene extract, podophyllin, a time-honoured laxative. The irritant resin which constitutes the active principle is present in sufficient amounts in the dry powdered root to constitute a hazard. Workers who feed the root into the grinder must be protected by goggles and dust respirators to prevent irritation of the mucous membranes. In exceptional cases, even the skin may be irritated by the dust. Failure to use protective equipment results in a characteristic, very painful conjunctivitis and keratitis, which is delayed in its onset for four to six hours after exposure and lasts several days. In its mild form this irritation subsides spontaneously under treatment with antiseptic and local anaesthetic ointments; a more severe form,

caused by massive exposure to the concentrated podophyllin, may produce diffuse infiltration of the cornea, or even ulceration.

Penicillin.—The extraction of penicillin from mould cultures, though more modern in date, nevertheless properly should be classified with older processes of pharmaceutical manufacturing. It has, in my experience, presented one exposure which, though not toxic, had a sufficient nuisance value to require medical investigation. The first penicillin was grown in shallow trays. At one time, many of the cultures were being contaminated by *Aspergillus niger*, which matured and sporulated abundantly. The contaminated cultures were worthless, but had to be dumped in order to sterilize and re-use the pans. The dumping released dense clouds of black spores into the air; the workmen inhaling the dust found their nasal mucus and their sputum stained black for many hours thereafter, and were thus thrown into a mild panic. It was difficult to reassure these men on the grounds that the mould was *probably* non-pathogenic, especially since nothing in the literature could be found concerning exposures of similar magnitude. However, the passage of time and the continued good health of the workmen disposed of all our fears, and the advent of deep-tank culture methods rendered this particular nuisance obsolete.

Solvents

The solvents used to extract active principles from crude drugs are numerous and varied. Methyl alcohol is not commonly used. Ethyl alcohol offers medical hazards only to the extent to which it is denatured with more toxic materials.

12-A. The most available form of anhydrous ethyl alcohol in the United States is formula 12-A, which contains 5 per cent. of benzene. The hazards of this material arise from the tendency of chemical workers to regard it as alcohol pure and simple, and to handle it with corresponding carelessness. To the industrial physician it presents another difficulty: measurements of its concentration in the air are complicated by the presence of the alcohol. Instruments based on the combustible vapour principle give readings which can be interpreted in terms neither of pure alcohol nor pure benzene, and the colour development in the butanone test is affected by the presence of the alcohol. However, I am able to report that a group of two or three workers who were employed for some five years in almost daily contact with concentrations of 12-A alcohol vapour sufficient to cause stinging of the eyes and an overpowering odour failed to show any change in blood counts, or other signs of ill-health. Butanone tests made during the heaviest exposure showed concentrations of benzene ranging from 20 to 100 parts per million, as nearly as could be estimated with the anomalous colour-development.

Benzene.—Benzene itself is, unfortunately, such an excellent solvent for many active principles, as well as for numerous important synthetic chemicals, that it constitutes a major problem in the pharmaceutical industry. This is not the place to describe or discuss the well-known facts about acute and chronic benzene poisoning, except to affirm from my own experience that these well-established facts are still completely unknown or disregarded in more backward works, and that they cry out for more popular diffusion among workmen and foremen, even in the most progressive organizations. Accordingly, this review will present only those observations on the control of chronic benzene poisoning which have proved useful or pertinent in my own experience.

This experience covers eight years' observation of a group of some 150 workmen in a chemical manufacturing department, in which benzene is handled in scores of processes, in amounts ranging from a few litres to a thousand gallons, and under conditions ranging from the very best closed methods to the most primitive and dangerous ones. The exposures are essentially intermittent; grab samples of air have shown concentrations as high as 3,000 parts per million, and as low as 0 parts per million. Shifting men from one process to another has been a characteristic feature of this department; consequently, though some work periods involve no exposure to benzene for months, each man must be observed for signs of poisoning at all times, since all are exposed at one time or another—and to unpredictable degrees.

The mainstay of preventive medicine in this situation continues to be periodic determination of the blood count of each man every three months. If suspicious or abnormal values are observed, the interval of examination is shortened, and investigation of the clinical and occupational details of the individual case is undertaken. The details of this system are described in full elsewhere (Watrous, 1943*a*). Suffice it to say here that arbitrary limits have been set up to define suspicious and abnormal values of the blood counts. In fixing these limits, the industrial physician should bear in mind the normal variation which exists in all biometric data; this variation can be conveniently visualized by constructing frequency-distribution curves for the various quantities measured. In my opinion, no other method approaches this one in completeness and ease of comprehension, and it should be universally used to describe blood-count statistics for any group. Fig. 1 is a series of frequency-distribution curves for my group of workers, covering the period May, 1945, to August, 1946, and representing 880 complete blood counts on 200 individuals.

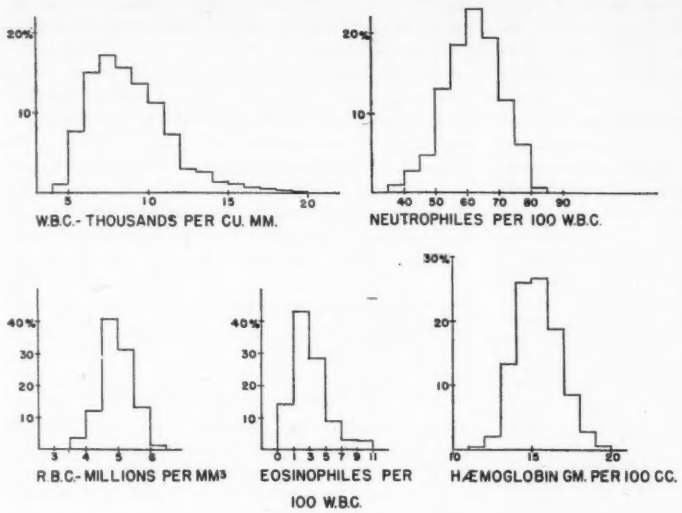


FIG. 1

Though other investigators (Greenburg and others, 1939) have found that changes in the size of the erythrocytes and very mild anaemia are the earliest haematological signs of benzene poisoning, I have not found these indices reliable. The most constant early sign of poisoning, in my experience, has been a progressive decline in the total white count to values below 5,000 per c.mm. I have not found this to be accompanied by any consistent alteration in the ratio of lymphocytes to granulocytes, or any definite trend in the erythrocyte count or haemoglobin content of the blood. Leukopenia persisting below 5,000 cells per c.mm. has been my criterion for complete removal of the worker from the chemical manufacturing department; such measures have been required seven times in eight years, and in each case the blood returned to and remained normal. The justification for this method of detecting benzene poisoning, and for the arbitrary values adopted as suspicious and abnormal, rests, therefore, on this limited experience. All that can be said for the method is that it has apparently prevented the occurrence of any case of irreversible bone-marrow damage over an eight-year period.

In my limited experience, determination of urinary sulphate ratios has not been useful. The fact that exposure to benzene is present may be determined by the physician's nose as he walks through the works, and may be proved quantitatively at any given time and place by air sampling. Urinary sulphate ratios add nothing to this knowledge, except to indicate that a given individual has absorbed benzene during a given period. Because of the enormous variation in sensitivity of individuals to benzene exposure, proof of absorption is no indication of damage, just as a normal sulphate ratio is no guarantee of absence of damage. The condition of the bone marrow is of the greatest importance, and this is most accurately reflected in the blood count. However, mere passive waiting for signs of bone-marrow damage to appear is no adequate programme for the prevention of benzene poisoning ; it is, rather, an indispensable last line of defence. If no other division of the industry is charged with the task of inspection of the work-place, air sampling, and the design of closed or ventilated equipment, the industrial physician must assume these duties. In any case, he must be fully informed of all activities relating to industrial hygiene and preventive engineering which take place in the factory, and should play an active part in furthering such work.

Chloroform and ethylene dichloride.—Chloroform and ethylene dichloride (1,2-dichloroethane) are occasionally used to extract alkaloids and other fat-soluble principles. Both solvents are liver poisons, and men working with them under ordinary conditions may develop certain vague symptoms which are referable to the gastro-intestinal tract and which suggest very slight liver damage. These consist of anorexia, a heavy feeling in the epigastrium, and fatigue. At this time the urine may give a positive test for urobilinogen, and in my experience this is an indication for transferring the workman temporarily to other employment. Amyl acetate and ethyl ether are other solvents occasionally encountered in vegetable extractions. Neither has proved especially toxic in my experience; the former because its strong odour has a deterrent effect on those who are in danger of over-exposure, the latter because of its very low inherent toxicity.

Alkaloids

The purified extracts of vegetable drugs include all the alkaloids which are used in therapeutics: atropine, hyoscine, scopolamine, emetine, aconitine —all powerful poisons which may cause illness if handled by careless or untrained workers. A common sight in the medical dispensary of a pharma-

ceutical industry, and a baffling one for the novice, is the single widely-dilated pupil caused by the entrance of minute particles of one of the belladonna alkaloids into the worker's eye in the form of dust. This may be seen even in persons who merely walk through the manufacturing department. One application of eserine ¼ per cent. ointment to the affected eye, after thorough irrigation with normal salt solution, will usually correct the pupillary dilatation within a few hours.

It is quite possible for a workman, if improperly instructed and protected, to develop acute poisoning by inhaling the dust of pure alkaloids of the belladonna group. One such case which I observed was that of a chemical worker 31 years old who had been grinding pure atropine sulphate through a fine-mesh sieve. His foreman had failed to impress upon him the necessity of wearing a dust respirator. He presented himself in a mildly inebriated state, complaining of blurred vision and dryness of the mouth. The pupils were widely dilated, the skin was flushed, and the pulse was 132. The patient was persuaded, with some difficulty, to rest in bed, where he tossed about, talking incessantly in a disoriented fashion. It was decided to administer eserine or pilocarpine in fractional doses intravenously, and here we encountered a difficulty which all physicians in charge of pharmaceutical works would be well advised to keep in mind: there was no preparation of eserine or pilocarpine at hand in a form suitable for parenteral injection.* The emergency was met by asking the pharmacologist's laboratory to weigh out and dissolve eserine in the same way as they would do for animal experiments. Repeated doses of 1 mg. were injected intravenously, each injection being followed by a period of observation, in which the condition of the pulse and the pupils was the most informative index of the patient's condition. After four injections the pulse had slowed to 102 and the patient was out of danger. There were no untoward after-effects, and the man was back at work the next day.

Aconitine hydrobromide may also give rise to acute poisoning if handled in the form of the pure powder. In one mild case which I observed, the symptoms were identical with those produced by a strong cigar in a person not used to smoking: there were pallor, weakness, nausea and vomiting, and cold sweat. The illness subsided in about thirty minutes; it was caused by the inhalation of dust while weighing a small amount of aconitine hydrobromide on an ordinary laboratory balance without using protective equipment.

In my experience emetine hydrochloride has never produced industrial systemic poisoning, but it is a local irritant; not infrequently, workers filling ampoules with the 6·5 per cent. solution may splash a drop in one of their eyes. A painful chemical conjunctivitis results, which requires about 48 hours to subside.

One unusual toxic exposure which came to my notice was the result of weighing some 500 g. of pure desiccated scarlet fever toxin, prepared by the method of George and Gladys Dick. The light, fluffy powder was readily dispersed in the form of dust, but no one had thought to warn the pharmacist about protection against this hazard. He presented himself the next day with a sore throat, a typical strawberry tongue, and an erythematous rash. There was no fever; repeated tests revealed no albumin in the urine. The symptoms had subsided the next day. The patient had never had scarlet fever.

The Hazards of Organic Synthesis

Organic chemical synthesis presents industrial hazards of three main types. Firstly, the active agents used to attack and modify the structure of organic compounds are, by their very nature, exceptionally able to attack and modify the organic compounds of the human body, thus producing highly poisonous effects. Secondly, the intermediate compounds in most organic syntheses are often characterized by the readiness with which they enter into chemical combination with other organic matter; they are active. This often confers toxic properties of great variety upon them. Thirdly, the final products, though they are medicines designed to be introduced into the human body, may nevertheless produce severe poisoning under conditions of industrial exposure.

Chlorinating Agents

Of the active agents widely used in organic synthesis, the chlorinating agents form a group which very commonly produces illness when improperly used. The common members of this group include chlorine, phosphorus oxychloride ($POCl_3$), carbonyl chloride or phosgene ($COCl_2$), thionyl chloride ($SOCl_2$), and phosphorus pentachloride (PCl_5). Chlorine and phosgene are gases, phosphorus oxychloride and thionyl chloride are liquids which vaporize readily at normal temperatures, and phosphorus pentachloride is a solid, of which I have had no personal experience. The first four are lung irritants and, therefore, may produce pulmonary oedema if inhaled in sufficient amounts. Their warning properties vary. Chlorine gives good warning of its presence; thionyl chloride and phosphorus oxychloride cause considerable irritation of the mucous membranes, but may be said to have only fair warning properties; phosgene gives

* Prostigmine, or prostigmine methyl sulphate, are suitable for this purpose, and should be kept available wherever belladonna alkaloids are being handled.

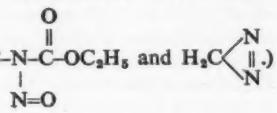
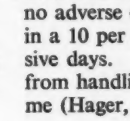
very poor warning. The most excellent engineering is required to prevent accidents when these chemicals are used in a manufacturing process, since, in addition to being poisons, they are highly corrosive to common metals; ordinary ventilating equipment, condensers, pipes, and tanks are apt to be destroyed within a few weeks. The leakage which may then result is extremely dangerous. Ordinary canister-type masks are not safe in such circumstances; repair workers should be equipped with air-supply masks or closed oxygen systems.

Sulphonating Agents

Of the sulphonating agents, chlorsulphonic acid ($HOSO_2Cl$) is extensively used in the manufacture of *p*-acetylaminobenzene sulphonyl chloride, a necessary intermediate for most sulphonamides. The fumes of the acid itself are highly irritating, and in many sulphonation reactions HCl gas and SO_3 are given off. It is often not economically feasible to trap these irritant by-products in a small synthesis, and they are often vented into the outside air. This is a bad practice, which will cause a large amount of bronchitis and conjunctivitis under adverse wind and weather conditions. Scrubbing towers of simple and cheap design, or very high stacks, are usually required to eliminate the nuisance. Other common sulphonating agents, concentrated H_2SO_4 and fuming sulphuric acid (oleum), are too familiar to require much discussion. However, it is well to remember that the heat of reaction of oleum and water is so great that there is some question as to the proper method of washing this acid off the skin, if it should be spilled. We recommend liberal dousing with anhydrous ethyl alcohol for the first wash, to be followed immediately by streams of water.

Methylating Agents

A common methylating agent used in the pharmaceutical industry is dimethyl sulphate ($(CH_3)_2SO_4$). It is a highly corrosive, volatile liquid, possessing vesicant and lung-irritant properties. It must be handled with the same care as the liquid chlorinating agents described in a previous section. Its warning properties are only fair.

The laboratory chemist is sometimes tempted to use two methylating agents of extreme toxicity because they make possible certain very elegant syntheses. These are nitrosomethyl urethane and diazomethane.  ( .)

The latter may be obtained by treating the former with alcoholic KOH, and is an extremely poisonous, yellow, odourless gas, described in the German literature of 1895, but having received scant attention since then. Von Pechmann (1895) stated that nitrosomethyl urethane caused 'red, itching areas and blisters to appear on the skin. Inhalation of its sweetish vapour causes severe bronchial catarrh, as well as a painful irritation and disturbance of accommodation of the eyes. Since these symptoms are not unlike those produced by diazomethane. it seems probable that the toxicity of nitrosomethyl urethane is due to its conversion to diazomethane in the body.'

The difficulty which these compounds would present if used in large-scale production may be imagined by considering the effects which I observed in two laboratory chemists who made up a few ounces to use in an experiment. In both cases the chemical was spilled on the operator's hands. There appeared to be a latent period of five to ten days between the exposure and the appearance of the dermatitis. The first symptom was a painless erythema which, after two to four days, developed into a severe, itching, uniform erythema, with marked swelling of the skin. At this time the skin assumed a peculiar dusky, cyanotic appearance, and itching was pronounced, No blisters appeared at any time. In the severe case, the phase of acute swelling lasted about five days and then subsided, being followed by an extensive desquamation of the affected skin.

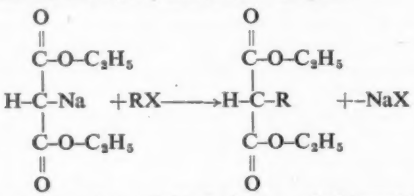
These two cases, fortunately, represent my only experience with this compound, since it has never been thought feasible to introduce it into large-scale manufacture. I was informed, however, by the director of synthetic chemistry of another large American chemical works, that whenever they manufactured nitrosomethyl urethane, reactions occurred in the workers despite all possible precautions. They were finally obliged to discontinue manufacture of the compound for this reason.

Experiments performed by R. K. Richards (personal communication) demonstrated that nitrosomethyl urethane painted on the shaved skin of rats at twenty-four-hour intervals will kill the animals after two applications. Purplish discoloration of the skin appeared in one of three animals. Death was evidently due to haemorrhagic oedema of the lungs, probably caused by inhalation of vapour from the skin. Nitrosomethyl urea ($H_3CN(NO)-C(=O)-NH_2$), another compound

from which diazomethane may be generated, showed no adverse effects when painted on the skin of rats in a 10 per cent. alcoholic solution for four successive days. However, one case of severe dermatitis from handling this compound has been reported to me (Hager, personal communication).

Alkyl Halides

The alkyl halides are extensively used in synthetic chemistry for the purpose of adding methyl and other alkyl groups to compounds, by the general reaction: $R\text{–}Na + R'X \rightarrow R\text{–}R' + NaX$. They find extensive use, particularly in the synthesis of barbituric acid derivatives, in which a large variety of alkyl groups are linked to the middle carbon of the malonic acid or the cyanoacetic molecules:



Common members of this series are ethyl bromide, *n*-butyl bromide, isopropyl bromide, 1-methyl-butyl bromide, and many others, limited in variety only by the number of alcohols which may be usefully substituted in the barbiturate molecule. Methyl bromide and benzyl chloride find application in other syntheses. The literature dealing with the toxic properties of these compounds as a group is limited largely to reports of experiments on animals (Flury and Zernik, 1931), but a few of the more noxious members of the series have given sufficient trouble to cause extensive comment for themselves individually.

Methyl bromide.—Leading the list is methyl bromide, unquestionably the most toxic, which may produce disturbing symptoms in concentrations below 35 parts per million (Watrous, 1942). I have had no experience with this compound in its capacity as a methylating agent, but at one time during the war a number of pharmaceutical manufacturers in the United States were requested to fill the liquid into glass ampoules for military use as a delousing agent. Widespread difficulty was encountered at that time, not only from inhalation of the vapour, but especially from the vesicant action of the liquid, which had previously been reported in the literature but was not widely known at that time. This vesicant property is also present in benzyl chloride, but is absent in ethyl bromide, isopropyl bromide, and 1-methyl-butyl bromide. I have observed a small group of workers exposed intermittently to ethyl bromide vapour in concentrations up to 1,500 parts per million, to benzylchloride up to 500 parts per million, and to 1-methyl-butyl bromide up to 920 parts per million. No systemic symptoms were complained of by these men over a period of years, though the vapour of benzyl chloride produced some conjunctivitis and irritation of the upper respiratory tract in a few instances. However, no one who has witnessed the insidious and deadly action of methyl bromide, with its delayed effect upon the central nervous system, can regard any of the lower alkyl bromides with anything but distrust, and I believe that closer observation of men chronically exposed to these compounds may reveal mild degrees of damage. In any event, most members of the alkyl halide series are powerful anaesthetic agents, and must be handled with caution for that, if for no other reason.

Sodium and potassium cyanide.—Sodium and potassium cyanide are frequently used in organic synthesis to form nitriles with organic halides:

$$NaCN + RX \longrightarrow RCN + NaX$$

It is a fact, not peculiar to the pharmaceutical industry, that the cyanides themselves, despite their great toxicity, seldom are the cause of serious poisoning under ordinary conditions of use. Such poisoning as does occur is usually the result of an accident in which acid is allowed to come in contact with unreacted cyanide. In such an event, some of the largest handlers of cyanide in the United States favour the antidotal measures described by Chen and others (1944), in which 10 c.cm. of 3 per cent. sodium nitrite are injected intravenously, followed by 50 c.cm. of 25 per cent. sodium thiosulphate. Boxes containing all the necessary materials for such treatment are sometimes prepared and kept ready for emergencies in the work-rooms where cyanide is handled. Many of the nitriles have toxic properties resembling cyanide itself, and in general they must be handled, if volatile, with extreme care. In one case of exposure to benzyl cyanide (benzonitrile) which I observed, the symptoms consisted of vertigo, faintness, ataxia, pallor, and weak pulse, followed by headache and vomiting the next day. The general properties of this compound are described by Heffter (1923).

Acetylating Agents

Acetylating agents used in organic synthesis are numerous. Glacial acetic acid, acetic anhydride, monochloracetic acid, and dichloracetic acid are a few. These compounds, in varying degrees, have the peculiar property of producing extensive bullous desquamation of the skin, especially on the palms of the hands, with little or no warning. It is not uncommon to see separation of the entire upper layer of the skin on both palms in workmen who spill these substances on their hands. In most cases the victim is unaware of anything except a mild stinging or itching sensation and, therefore, does not trouble to wash off the chemical or take any other action to

halt its destructive effect. When such accidents are reported promptly, soaking the affected parts for as long as four hours in sodium bicarbonate solution will generally prevent any damage; these very protracted soaks are essential to permit the reagent to diffuse out of the skin instead of into it. The acetylating agents are, of course, also lung irritants, but their warning properties are such that pulmonary complications are seldom seen.

Condensing Agents

What might be called the condensing agents form a miscellaneous group of considerable chemical activity. Sodium methylate and sodium ethylate are widely used in the chemical synthesis of drugs. They are usually made up just before use by adding sodium to the appropriate alcohol in a closed tank or still; the next step in the reaction is then usually carried out without delay in the same container. In this way, the workmen are never directly exposed to the compound except by some unusual accident. The chief danger from the compounds themselves is their corrosive effect upon tissues. The hazard in making them arises from the presence of sodium metal and hydrogen, with the possibility of explosion and fire if improper methods are used. Concentrated sulphuric acid, phosphorus oxychloride, phosphorus pentachloride, and phosphorus pentoxide are often used as condensing agents because of their extreme avidity for water. The same property endows them with corrosive properties in respect to human tissue, most of which have been previously discussed.

Nitrating Agents

Nitrating agents find occasional use in the pharmaceutical industry, though in general these reactions are more common in the heavy chemical industry which supplies the basic chemicals from which fine chemicals are made. The dangers of corrosive action, explosion, and inhalation of NO_2—the inevitable accompaniments of any nitration—are so familiar as to need no further comment.

Organic Reductions

Organic reductions are common in the synthesis of medicinal chemicals, and are most usually brought about by the addition of finely-divided iron or zinc, with an acid, to the organic substance. The evolution of hydrogen always creates the hazard of explosions, and the storage, handling, and recovery of finely-powdered zinc carries with it certain dangers which are not commonly recognized. Dry powdered zinc, if dispersed as a dust in air, is highly explosive within certain limits; wet powdered zinc may undergo oxidation and is subject to spontaneous combustion (Brown, 1941).

Toxic Intermediate Compounds

To describe all the toxic intermediate compounds which might be encountered in the organic syntheses peculiar to the pharmaceutical industry would require much space, and a great deal more unpublished knowledge than any one individual is likely to acquire at the present time. I shall, therefore, limit the following discussion to compounds of which I have personal knowledge or experience, and to those which present especially difficult or little-known properties.

Dichlorethyl acetate.—In one method of synthesizing sulphathiazole, the intermediate compound aminothiazole is made by adding chlorine to vinyl acetate and by condensing the resultant dichloroethyl acetate with thiourea. Dichloroethyl acetate is an unstable liquid with a sharp odour, possessing vesicant and lung-irritant properties of somewhat lesser degree than mustard gas. It produces conjunctivitis and tracheitis in low concentrations in the vapour phase. Liquid leaking from the equipment may produce blisters; small amounts of liquid entering the eye will cause corneal ulceration.

Aminothiazole.—Aminothiazole itself is a crystalline solid with a marked tendency to sublime at moderately elevated temperatures. Exposure to its vapour and dust causes dermatitis, some gastrointestinal symptoms, and a distinctive dark-brown pigmentation of the urine, not due to bile pigments or haemoglobin. Deichmann and his co-workers have investigated the toxicity of aminothiazole. They found that aminothiazole repeatedly inhaled at levels of 0·2 mg. per litre had a toxic effect on the lungs, liver, kidneys, and heart of guinea-pigs. The tissues of rabbits and rats exposed similarly demonstrated insignificant gross lesions; microscopic examination disclosed mild toxic degenerative changes in the liver and kidney. Two guinea-pigs which died after four and forty-one seven-hour exposures to an atmosphere containing 0·025 mg. per litre were found to have oedema, congestion, and emphysema of the lungs, and fatty degeneration of the liver. Three guinea-pigs which survived forty-two such periods of exposure showed only slight hepato-cellular degeneration.

In workers exposed to the chemical in amounts varying from 0·1 to 3·0 mg. per cu. ft. (0·0036 to 0·11 mg. per litre), Watrous (1943*b*) found no evidence of liver damage, but occasionally there were anorexia, nausea, and vomiting. In three instances, a distinctive syndrome of urticaria followed by arthralgia appeared and ran a course lasting up to five weeks. The disorder closely resembled serum sickness. Further cases were prevented by

adopting improved method of handling the chemical. The handling of 2-aminopyrimidine, a material of somewhat similar properties and an intermediate in the synthesis of sulphadiazine, produced no such symptoms.

Astwood and his co-workers (1945), in their investigation of compounds possessing anti-thyroid effect, found aminothiazole to be about one-seventh as active on the thyroid gland as thiouracil. This property was discovered independently in France by Perrault and his collaborators (1944–5), who observed symptoms of hypothyroidism in a group of aminothiazole workers. The chemical is now reported (*J. Amer. med. Ass.*, September 28, 1946) to be in use in France as a medication for thyrotoxicosis, and some of the side-effects resemble the symptoms I observed in chemical workers. Three of my patients complained of excessive gain in weight, puffiness of the face and hands, and lassitude, but objective evidence of thyroid hypofunction was not definite enough to attract my attention at the time.

p-acetylaminobenzene sulphonyl chloride.—*p*-acetylaminobenzene sulphonyl chloride is a necessary intermediate in the synthesis of almost all the sulphonamides. It is prepared by sulphonating acetanilid with chlorsulphonic acid. The resulting crude chemical is a light-brown powder, somewhat unstable in the presence of moisture, and having a strong smell of acetic acid. The crude material is purified, and must then be thoroughly dried. The chemical is a moderately powerful primary irritant to the skin and mucous membranes, and may produce conjunctivitis, rhinitis, bronchitis, and dermatitis. In one unusual case, it produced bronchial asthma with a specific wheal formation when the diluted material was applied to a scratch on the skin. This is a very rare phenomenon in connexion with simple chemical compounds, as it generally indicates the presence of specific reagins in the blood.

The patient was a man 33 years old, employed for ten years in chemical synthesis. A few years previously, he had been exposed to the vapour of thionyl chloride in sufficient amounts to produce pulmonary oedema requiring treatment with oxygen. While recovering from this accident, he was exposed to the dust of *p*-acetylaminobenzene sulphonyl chloride, and gradually noticed an increasing susceptibility to this irritant, which finally provoked typical asthmatic attacks. He was shifted to a part of the factory at least 300 yards from the location where this chemical was prepared and dried, but whenever the wind blew in his direction from his former place of work, he would become dyspnoeic. On many occasions he was able to tell within ten minutes after the mechanical drier in the remote part of the factory had been placed in operation. A 1: 100 solution of *p*-acetylaminobenzene sulphonyl chloride in acetone was mixed with equal parts of water and applied to a scratch on the patient's forearm. Within a few minutes, erythema, itching, and wheal formation of the extent usually spoken of as four plus appeared at the site of the scratch.

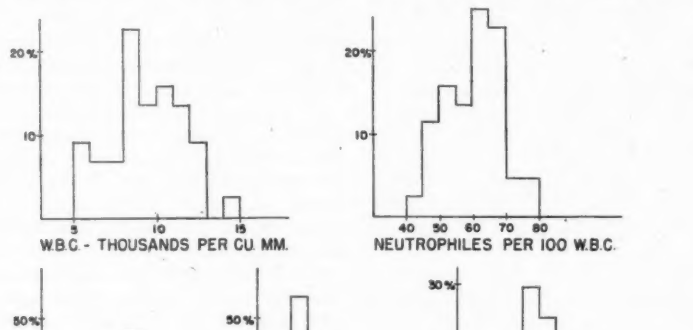


FIG. 2

A control scratch not treated with the chemical showed no reaction. The same solution was applied to the skin of four normal subjects after scratching; no erythema or wheal formation occurred. A 1: 10,000 dilution of the chemical produced no reaction on the patient's skin or on the skin of controls.

A small series of cases exhibiting specific atophy to simple chemical compounds, with more elaborate proof of reagin formation, will be referred to in another section.

p-acetylaminobenzene sulphonyl chloride.—*p*-acetylaminobenzene sulphonyl chloride was claimed to be the cause of aplastic anaemia in a lawsuit brought in one of the eastern states of the U.S.A., and therefore data on the blood counts of workers handling this chemical are pertinent. Fig. 2 represents the frequency-distribution of figures from 43 blood counts made on 6 workmen who handled this chemical steadily from May, 1943, to May, 1944. They were exposed to the crude material, the acetone solution, and the dust from the refined product. The concentration in the air was always less than 0·066 mg. per cu. ft.* By comparing these curves with those in fig. 1, it will be seen that no significant trend indicating depression of a haematopoietic activity can be detected. In the case mentioned, I was informed that the plaintiff had worked many years in another factory where there was exposure to benzene, and had only recently come in contact with *p*-acetylaminobenzene sulphonyl chloride in working for the company against which he filed suit.

Pentothal sodium.—Thiourea has already been mentioned as an intermediate in the synthesis of aminothiazole; it is also used in the manufacture of pentothal sodium. Thiourea is known to be a depressant of thyroxin formation. However, the dose required to produce this effect clinically is of the order of one or more grammes per day, and it is difficult to conceive of industrial exposure which would permit the absorption of this amount; in my experience, no toxic effect of any kind has occurred in men handling this compound. Organic compounds of sulphur in general tend to contain impurities of variable composition, usually foul-smelling, and of uncertain toxicity. Most of these compounds spontaneously liberate H_2S, and it is difficult to ascertain, in any case, whether the symptoms of intoxication are predominantly caused by this or by other sulphur compounds. In the purification of crude Pentothal Sodium, H_2S, mercaptans, and other disagreeable smelling compounds are present, and may produce headache, nausea, vomiting, faintness, and vertigo if not removed by proper ventilation.

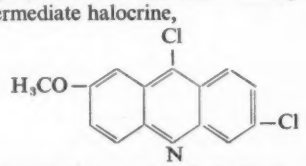
Carbon monoxide.—Carbon monoxide is an expected by-product of certain organic syntheses, as in the manufacture of phenylethylmalonic ester. This ester is formed by the condensation of phenyl ethyl acetate with diethyl oxalate; when the condensate is distilled, CO is liberated. Since the gas is quite pure and odourless, it gives no warning of its presence. Points which must be carefully watched in the design of equipment for such distillations are: discharging condensed steam into sewers, thereby carrying trapped gas to remote points; leaks in the exhaust line of the vacuum pump; and the provision of water seals on all floor drains communicating with the chemical sewer. Carbon monoxide is also produced when methyl or ethyl formate are condensed with ethyl acetate in the preliminary stages of synthesizing 2-aminopyrimidine. This toxic gas is, of course, also to be reckoned with in hundreds of locations in the pharmaceutical factory in which illuminating gas is used for fuel. Special problems arise where many gas flames are used for sealing glass ampoules in rooms which must be kept free of flying dust, or in which the moisture-content of the air must be kept low; in such circumstances, conventional exhaust ventilation may be difficult or impossible to use.

Arsenic.—All the intermediates of arsphenamine and its derivatives are potentially toxic because they contain arsenic. All these compounds are solids, and must be handled in the form of dry powders, with the production of dust. I have been unable to find any study of the toxicity of these materials under the usual conditions of manufacture, but observations made by Watrous and McCaughey (1945) indicated that intermittent exposure to the dust of arsenical intermediates at levels ranging from 0·001 to 0·015 mg. per cu. ft. did not give rise to any symptoms of chronic arsenic poisoning over long periods of time, though the amount of arsenic excreted in the urine was higher than normal. Enormous amounts of arsenic were found in the hair of some of these workmen who had no symptoms of poisoning; this was considered to consist of settled dust, firmly attached to the hair, but might prove very misleading in any medico-legal cases because of the importance attached to arsenic in the hair by the conventional teachings of toxicology and forensic medicine.

* This concentration was present at the exhaust outlet of a rotary drier, and was too irritating to be tolerated in the air of the workroom. It was determined by collecting the chemical in an impinger containing strong *aqua ammonia*, thus forming acetyl sulphanilamide, which was measured, after neutralization and hydrolysis, by Marshall's method. About 10 per cent. of the dust appeared to consist of sulphanilic acid, and thus gave a test by Marshall's method without hydrolysis.

Aniline.—Aniline is an intermediate in the synthesis of arsanilic acid; dimethylaniline is used as a solvent in the synthesis of aminopyridine. The toxicity of the former can hardly be over-exaggerated, since the accepted maximum allowable concentration of the vapour is scarcely more than that for such dangerous poisons as HCN, H_2S, and CS_2. The danger to untrained workers is more likely to consist of disregarding the presence of small splashes of the oil on their shoes, clothes, or gloves. For trained workers, using properly-ventilated equipment, the hazard consists chiefly of accidents in the machinery, with sudden massive exposure to the oil or its vapour. In my experience, there have been only two cases of marked methaemoglobinaemia, and both recovered with no other treatment than removal of contaminated clothing, rest in bed, and oxygen. In the aniline dye industry, I am informed, cases showing cyanosis of the lips are seen almost every day, and are regarded lightly, except when accompanied by some other intoxication, such as the ingestion of alcohol. In the dye industry, also, exposure to dimethyl aniline is sufficiently intense to produce methaemoglobinaemia similar in every way to that caused by aniline; in my own experience dimethyl aniline has never caused any symptoms, probably because it was not extensively handled.

Halocrine.—In the manufacture of mepacrine (quinacrine dihydrochloride), many of the intermediate products are very active, and may constitute primary irritants or sensitizers. In my experience, the intermediate halocrine,



has demonstrated a marked ability to sensitize the skin of susceptible workers. Exposure to the chemical dust in some of these men caused a severe contact dermatitis, necessitating permanent transfer to other work.

Final Products of Synthesis

Mepacrine and acriflavine.—Among the final products of organic synthesis, mepacrine itself deserves mention as an especially troublesome primary irritant and sensitizer. Rather extensive compressing and grinding, thrice repeated, are necessary to prepare the material in the form of tablets; dust control during these operations is mandatory, but extremely difficult, because of the structure of the machines involved. In a study made at the Abbott Laboratories (Watrous, 1944), exposure to the dust at levels between 0·35 and 4·2 microgrammes per litre was sufficient to cause conjunctivitis in more than half of the workmen, and dermatitis, rhinitis, and stomatitis in about a third. Similar symptoms have recently been described by Barlow and others (1946). Acriflavine, another dye of the acridine series, possesses similar, though weaker, irritant properties; workers bottling tablets of this dye often suffer from a conjunctivitis of considerable severity if they transfer the material to their eyes by injudicious rubbing with dust-stained hands.

Nicotinic acid.—Nicotinic acid and its salts have a peculiar effect upon the skin of certain workers who handle these chemicals in bulk: this consists of a diffuse erythema on the exposed parts of the skin, usually not accompanied by itching, and resembling sunburn in appearance. It is usually transient, disappearing in from twelve to twenty-four hours, though sometimes it assumes a papular character on the second day and lasts several days. The amide of nicotinic acid has never produced this rash in my experience (Watrous, 1939).

Powdered penicillin.—Dry powdered penicillin has proved to be a potent sensitizer and skin irritant in all the American factories where it is handled. It may produce follicular erythema, diffuse papular rashes on the exposed parts of the body, or, in some cases, severe generalized urticaria which persists for days or weeks after exposure ceases. In the latter cases it seems probable that a generalized sensitivity has been created by previous contact with the substance, and that the urticaria results from systemic absorption of the powdered drug by inhalation. In a series of four cases showing industrial dermatitis from exposure to penicillin, Friedlaender and others (1946) found the patients to be sensitive to pure crystalline penicillin rather than to any particular impurity in the commercial product.

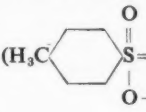
Local anaesthetics.—The local anaesthetics, procaine, butyn (butecaine sulphate), and butesin (*n*-butyl aminobenzoate), form a group of substances more or less prone to cause sensitization and dermatitis upon prolonged contact with the skin. The tendency for procaine to sensitize the skin of dentists and others who frequently spilled solutions on their hands was recognized many years ago, and was one of the factors which made prepared solutions in cartridges so popular with dentists. Women engaged in filling cartridges with sterile solutions of procaine are subject to a characteristic occupational dermatitis caused by excess solution overflowing from the tubes and running down their arms. This usually mild, papular dermatitis is specifically located along the path taken by the drops as they

run from the wrist to the elbow on the flexor surface of the forearm. It may be prevented by equipping the workers with rubber gloves with turned-up cuffs to catch the liquid; it promptly subsides when contact with the solution ceases. Some operators may be returned to their work after the dermatitis subsides, and appear to suffer no further inconvenience. Others experience a recurrence of the condition in a more severe form, and are thus classified as permanently excluded from work with procaine. Butyn and butesin have produced much less industrial dermatitis in my experience, possibly because they are marketed in forms not requiring such intimate contact with the skin in the process of manufacture.

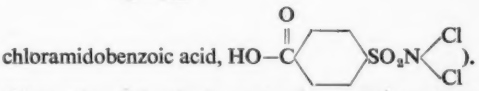
Neoarsphenamine.—Neoarsphenamine, apart from its arsenic content, may occasionally provoke sensitization of the skin in those who pack it in ampoules. In such cases the minute amount of dust which settles on the skin during the process may cause papular rashes on the exposed skin areas. In one such case the skin was so sensitive to contact with the drug that a patch test made with a few milligrammes of the powder exhibited vesiculation within twelve hours. Such marked reactions, however, are rare; patch tests are usually negative, but many mild dermatoses of this kind subside when contact with the drug ceases and recur when it is resumed. Neoarsphenamine may also act as a primary irritant if it is allowed to accumulate under the nails of those handling it. This is especially prone to occur in women who affix labels to the sealed ampoules. Occasionally an ampoule breaks in the machine, and the spilled powder is wiped up with a damp cloth. The cloth soon becomes stained deep brown as the wet powder oxidizes. If this oxidized material accumulates beneath the nails of the operators, a deep brown stain is produced, and the distal edge of the nail becomes exquisitely tender, with signs of inflammation extending a few millimetres proximally. Hot soaks of 10 per cent. sodium thiosulphate, with temporary change of work, usually bring the condition under control. To prevent it the wiping rags should be moistened with sodium thiosulphate and should be frequently changed.

2-methyl-1,4-naphthoquinone.—2-methyl-1,4-naphthoquinone, a synthetic form of vitamin K, has the property of sensitizing the skin and producing dermatitis. Workers who handle this chemical present a dark-brown staining of the skin, and may later show papular or eczematoid dermatitis. These phenomena were noted in the works at the time when the chemical was first being prepared for clinical use, but were not considered significant, since the medication was to be administered orally. However, Page and Bercovitz (1942), who had been successful in administering 2-methyl-1,4-naphthoquinone to infants by percutaneous inunction, encountered dermatitis in five out of nine adults to whom they gave the material by the same route. Itching, erythema, oedema of the skin, and even ulceration were observed in some of the subjects.

Sulphonechloramides.—At least two sulphonechloramides which are used as antiseptics or disinfectants have rather unusual properties as local irritants and sensitizers. These are chloramine-T



and "Halazone" (*p*-sulphonedichloramidobenzoic acid,



). When these chemicals contaminate the working environment in the form of dust, they may produce dermatitis, rhinitis, conjunctivitis, and bronchitis in their capacity as primary irritants. Their most remarkable property, however, is their ability to produce specific atophy in certain individuals. These workers, after rather heavy exposure to the chemicals, gradually become more and more intolerant to them, and begin to exhibit typical asthmatic symptoms instead of the initial picture of simple irritative bronchitis. Finally, as the syndrome is fully developed, they are unable to encounter the minutest quantities of the chemicals in the air without suffering an asthmatic attack.

A series of fourteen such patients, investigated by Feinberg and Watrous (1945) all gave whealing responses to scratch tests performed with chloramine-T solutions in dilutions ranging from 1: 10 to 1: 10,000. Four of the more sensitive patients had reagins in their blood, which were demonstrated by passive transfer. In other words, these patients gave every reaction to this simple chemical compound which one finds in typical allergies of the atophic variety, formerly believed to be provoked exclusively by proteins of high molecular weight. In view of the serious and permanent disability imposed by asthma, no pharmaceutical workers should ever be subjected to heavy exposure to chemicals of this general type.

Mercury poisoning.—The hazard of mercury poisoning must be considered in the pharmaceutical industry in connexion with three occupations: the manufacture of organic mercurial antiseptics, the moulding of mercury bichloride and mercury oxycyanide tablets, and the use of mercury manometers. In making solutions of organic mercurial

antiseptics, it is often necessary to allow dilute solutions to age for several weeks in 1,000-gallon tanks to eliminate precipitation when the product is finally filled into bottles. It is not unusual to observe a fine film of tiny droplets of metallic mercury on the glass lining of the manholes of such tanks—ample evidence that the atmosphere above the solution must contain mercury vapour. In my experience, no cases of poisoning have ever resulted from this particular cause, but under unusual conditions there is no doubt that the possibility of mercurial poisoning would be present.

In the moulding of antiseptic tablets of mercury bichloride or mercury oxycyanide, a moist powder or mass is rubbed into a mould with a spatula. The tablets are then ejected by means of a male punch-plate, spread on trays, and dried in an oven. In another method the tablets are punched on a machine, using a dry granulated form of mercury bichloride. In either case the chief danger is systemic absorption of mercury by inhalation of dust; minor symptoms may be caused by the local irritant action of mercury salts on the skin. Tablet-moulders should be carefully selected from a group of older, responsible employees who have had enough experience to develop a wholesome respect for and knowledge of poisons. They should be supplied with efficient dust masks and rubber gloves, and should carry out their moulding under ventilated hoods. The unloading of dried tablets should be done in hoods, and any subsequent counting and bottling must be surrounded with even more stringent precautions. When such precautions are in effect, air levels of mercury are of the order of 0·002 mg. per cu. ft. Under such conditions no cases of mercurialism have come to my notice.

In the laboratory, or in certain manufacturing operations, mercury offers peculiar advantages as a liquid of high specific gravity. It finds extensive use in manometers, in apparatus for gas analysis, and in simple devices for maintaining inert gases at a constant positive pressure. The latter instance has considerable manufacturing importance in filling ampoules which must be protected by a layer of inert gas above the liquid or solid. To obtain a constant flow of inert gas from high-pressure cylinders, some type of pressure-release must be provided; a tube immersed in a few inches of mercury is effective for this purpose. The constant bubbling of the gas through the liquid must carry some mercury vapour into the work-room, and there is, of course, the inevitable spillage which occurs when such devices are adjusted or moved frequently. Here, as in chemical laboratories, one cannot assume the concentration of mercury vapour to be insignificant; actual measurement of the air content should be made periodically to be sure this is so.

Stilboestrol.—The chemical synthesis of diethylstilboestrol is hazardous in its final stages, in which the drug is purified by crystallization from various fat solvents such as ether and benzene. As Fitzsimons (1944) has pointed out, spillage of these concentrated solutions on the skin may lead to direct absorption of toxic amounts of stilboestrol, with the production of gynaecomastia in male workers. Spilling small amounts of the solution on work-benches leaves a deposit of fine powder which may contaminate the air as dust.

To Fitzsimons's twenty cases I can add two more which I observed in young men who purified diethylstilboestrol, and several others of similar causation and course have been reported to me (Passarelli, personal communication). In these cases the patients complained of moderate to severe loss of libido. In the two men I observed, a moderate normocytic anaemia developed concomitantly with the hypertrophy of the breasts; in one case the red count and haemoglobin fell from 4·4 to 3·7 million and from 15·6 to 12·6 g. per 100 c.cm., respectively. In the other case the fall was from 5·0 to 3·9 million and from 16·0 to 14·4 g. This caused alarm in view of the depressant effect of diethylstilboestrol when large doses were given to animals (Von Haam and others, 1941; Castrodale and others, 1941). However, when the patients were removed from contact with the drug, their blood quickly returned to a normal state and the other symptoms gradually subsided.

The physical hazard in exposures of this kind, in factories where good industrial medicine is practised, is probably far less than the psychological hazard. The fact that an industrial poison may have a feminizing effect is something new under the sun, and its impact upon suggestible young men with neurotic leanings can be disastrous. In industries where poor relations obtain between labour and management, or where industrial medical service is rudimentary, exposure to this chemical may be expected to be a rich source of litigation. I know of one instance in which the manufacture of diethylstilboestrol was abandoned for this very reason. It is worthy of note that the mixing and handling of diethylstilboestrol in the diluted forms in which it is dispensed for clinical use have never, in my experience, given rise to any symptoms; the sole danger seems to arise in the handling of the pure chemical.

Morphine and codeine.—Tablets of morphine and codeine intended for hypodermic injection must still be hand-moulded in the pharmaceutical industry, since machine-made tablets would not dissolve quickly enough to be practical. The hand-moulding process involves much handling of the raw materials, and under certain conditions enough dust may be created to permit effective doses of these drugs to be absorbed. Cases of serious poisoning can scarcely occur, because of the relatively large amount of material which would have to

be absorbed by inhalation. However, it is not unusual for tablet workers to complain of drowsiness and lethargy if exposed to unusual amounts of dust. The suspicion that effective doses are absorbed in this way from the respiratory tract is strengthened by the observation that, when mixtures of morphine and atropine are being handled, pupillary dilatation and dry mouth may be observed in addition to the other complaints. No case of addiction, however, has ever come to my notice as a result of such exposure.

Veterinary preparations.—Many pharmaceutical manufacturers make certain products intended for veterinary use, and the physician whose knowledge is confined to the armamentarium of human medicine would little suspect what poisons are still in good repute in the art of healing animals. A tonic powder for horses may contain up to 2·5 per cent. of white arsenic; vermifuge capsules for animals may contain pure tetrachlorethane. Thus it may come to pass that packers are inadvertently exposed to dangerous amounts of arsenic, or soft-capsule makers to toxic vapours, in the innocent belief that material used as 'medicine' can hardly be dangerous! Such errors will be eliminated in the well-organized pharmaceutical works by seeing that the formula department affix special precautionary labels to all formulae containing poisons, and by including in instructions for compounding the formula details of all necessary precautions for handling the ingredients.

Miscellaneous Hazards

In addition to the specific hazards peculiar to the pharmaceutical industry, workers in this occupation are subjected to a number of other noxious agents common to other industries.

Radiant Energy

Radiant energy may endanger pharmaceutical workers in several different ways.

Ultra-violet light.—Exposure to ultra-violet light occurs in the arc-welding incident to the construction and repair of manufacturing equipment as well as in rooms devoted to the manufacture of synthetic vitamin D from ergosterol. In addition, so-called germicidal lamps have found certain applications in the packaging of products subject to spoilage from air contamination. The prime factor in the injuries inflicted by these modern devices is ignorance on the part of well-meaning persons who become enthusiastic about 'applying the benefits of modern science' to their tasks without understanding the fundamental principles involved. All radiant energy of wavelength too short to be perceived by the senses produces injury not immediately perceived by the senses, but this is a concept which modern man has not yet appreciated. However, he must learn to appreciate it if he is to survive much longer on this planet. In the near future pharmaceutical industries will probably be occupied with furnishing radio-active isotopes of chemical elements which will localize in specific tissues, such as the thyroid gland and the osseous system, and the safe handling of these substances can be guided only by rational processes, not by any pre-existing or familiar pattern of experience.

Visible light.—In the visual spectrum, an occasional source of complaint by industrial workers is the introduction of fluorescent lighting in workrooms formerly illuminated by incandescent lamps. Complaints of eye-strain, headache, and many other subjective symptoms will arise in suggestible individuals when any change is made in their environment, and such complaints may be disregarded when attributed to fluorescent lighting. The only justifiable complaint with respect to this type of illumination comes from those who work with rapidly-moving objects under lighting which does not include the proper ballast and diphasic circuits to eliminate the stroboscopic effect of fluorescent lamps.

In the pharmaceutical industry, ampoule-sealers are, by virtue of their occupation, specifically exposed to the effect of visible light. Their occupation involves daily gazing into gas flames used for raising glass to fusion temperature, as well as fine discrimination as to the proper temperature at which to draw off the fused neck of the ampoule to make a proper seal. These workers are prone to accept the belief that such work is hard on their eyes, and tend to attribute any occular defects which may arise in their lives to their peculiar occupation. The majority of sealers elect to wear tinted glasses to reduce the glare from the flames, but the tint cannot be too deep, because it would then diminish visual acuity necessary for handling the ampoules under ordinary illumination.

Glass containing praseodymium, and sold under the trade name didymium glass by the Corning Glass Works, Corning, New York, U.S.A., makes a very effective filter for this particular work. The main component of the glare coming from hot glass in a gas flame is due to the practically monochromatic yellow radiation of the sodium D lines. Didymium glass selectively absorbs this light, but passes enough of the other radiations of the visual spectrum to allow good vision in rather dim surroundings. The elimination of glare from the flame enables the worker to see the molten glass more clearly, and thus should reduce eye-strain.

To test the truth of the workers' frequent assertions that sealing was bad for the eyes, two surveys were made in which several visual functions of the entire sealing group were tested. An interval of one year separated the

surveys. The instrument used was the Bausch and Lomb ortho-rater, by means of which visual acuity may be measured for far and near objects, phorias may be detected, depth perception measured, and colour-blindness revealed. The tests were made on each eye separately, both with and without the corrective glasses, if any were worn. Twenty-seven of the employees tested in the first survey were available for the second. Of these, twenty-six showed either improved performance or no change in the second test, whereas one showed poorer performance. The great preponderance of those showing improved vision was attributed to the fact that many had become aware of uncorrected visual defects or poorly-fitting glasses in the first survey, and had taken remedial steps.

Infra-red light.—The use of banks of incandescent lamps radiating a high percentage of infra-red energy was applied in the automobile industry to hasten the drying of lacquer on rapidly-moving production lines, and has found at least one application in the pharmaceutical industry for the same purpose. Those who design such devices are rarely aware of the fact that intense infra-red radiation may produce cataract; therefore the industrial physician must inspect such installations and assure himself that no worker receives harmful amounts of this radiation.

Bacteria and Viruses

A small group of laboratory workers in any large pharmaceutical industry will necessarily undergo an occupational exposure to virulent bacteria and viruses. Even though such employees have had extensive professional training which is supposed to tender them extremely careful, accidents may occur; this is especially true where virulent cultures are handled in large quantities, as in the manufacture of vaccines. Several fatal infections with the virus of equine encephalomyelitis occurred in the United States in connexion with large-scale manufacture of vaccine (Helwig, 1940). As a result, experiments were carried out to determine a suitable immunization procedure to be applied to laboratory workers.

In 1939 a small group of laboratory workers at the Abbott Laboratories were given four injections of Abbott equine encephalomyelitis veterinary vaccine, mixed Eastern and Western types, diluted 1: 1 with normal salt solution. Each dose consisted of 1 c.cm. injected into the gluteal muscle. The doses were repeated at two- to three-day intervals. Six weeks after the vaccination, blood serum from the men in the group was tested for neutralizing power against the living virus. Only a slight increase in titre was observed. Accordingly, each subject received 0·5 c.cm. of undiluted vacccine. In 1940, Beard and others described a method which successfully immunized 100 exposed persons; 2 c.cm. of full-strength vaccine were injected into the gluteal muscle twice. At present the routine method of immunization at Lederle Laboratories, where this vaccine is still manufactured is to inject 0·5 c.cm. of Western type vaccine into one deltoid muscle, and 0·5 c.cm. of Eastern type into the other. The same doses are repeated in a week. Thereafter, one 'booster' dose of the same size is given annually (Hardy, personal communication).

Reagents, etc.

Several toxic hazards arise in large bacteriological or pharmaceutical laboratories where strong reagents, illuminating gas, and large amounts of glassware are used. A popular solution for cleaning glassware is a mixture of sulphuric acid and potassium dichromate. A chemist cleaning his own glassware rarely has enough contact with this solution to produce disease, but in large laboratories the division of labour tends to create exposures which may produce severe dermatosis. The hands are most affected, and tend to become hyperkeratotic and fissured. Extreme cases of this dermatosis may be seen in old photolithographers, who handle chrome etch with their bare hands.

One case of erosion of the nasal mucous membranes arose from the use of this solution as the result of a single accident. A well-meaning, but chemically naïve worker thought she might prevent contact of the solution and her hands by using a tray for the glassware, which could be immersed in the concentrated acid. Unfortunately the model tray which was used to try out the idea was made of iron galvanized with zinc. The violent evolution of hydrogen created a mist of acid chromate solution, which was inhaled with painful, though educational, results. Trays were later made of stainless steel.

Another laboratory hazard attends the use of glass wool, or of cloth made of spun glass fibre. In the preparation of packages for the administration of blood plasma during the war, rolled tape made of glass cloth was used in the filter assembly. Workers who cut and rolled this tape developed irritation of the skin on the flexor surfaces of the forearms, where their arms rested on the table top. This was eliminated by providing long cuffs of cellulose acetate.

Blood-plasma preparation required a few workers to spend almost half their time inside large refrigerators. The blood was centrifuged in cold rooms at about 40° F., and frozen plasma was stored in rooms close to 0° F. From these rooms, the workers would emerge into a working area at 70 to 80° F., and it was this frequent transition which caused all their complaints. Many assertions were made that this work was bad for the health, and that it caused frequent colds and coughs. However, the hazard was more mental than physical, and no increase in respiratory infections could be demonstrated objectively.

Chemical laboratory research workers are generally considered too well educated to do anything so foolish as poison themselves with the reagents they use. In my experience this assumption is unwarranted. Where such workers are exposed to benzene vapour, they require just as careful watching as any chemical labourer. One pharmaceutical manufacturer found leukopenia in five out of twenty research chemists. Most of these men had Ph.D. degrees, but they had received no instruction or special warning during their university studies and were unaware of any particular hazard in handling benzene. In reporting this, the Industrial Hygiene Division of the United States Public Health Service (Bloomfield, 1945) calls for adequate instruction in American universities concerning laboratory precautions for chemical research workers.

Miscellaneous hazards are encountered by the mechanics who install and repair the great variety of equipment needed in pharmaceutical works. Many large vessels used for chemical reactions must be lined with sheet lead, and the fabricating and repair of such linings is a skilled trade. Lead burners, because of this special skill, are likely to be steadily occupied handling lead only; they scrape, brush, file, and weld the sheet. The technique employed for welding lead sheet in the Abbott works requires the use of an oxy-hydrogen torch. This burns with a quiet, moderately hot flame, and has no tendency whatever to produce lead oxide fume; indeed, the flame seems to possess reducing properties which prevent any oxidation of lead. The scraping, brushing, and filing of the sheet produce mainly large particles which have no tendency to remain suspended in the air; however, the handling of old, corroded lead sheet would probably involve more dust. Six urinary lead determinations have been made on one lead burner over a period of nineteen months. These varied between 0·015 and 0·037 mg. per day. No symptoms of plumbism have appeared. The use of oxy-acetylene torches in fusing lead gives rise to abundant fume, and would be more hazardous. Other fumes encountered by maintenance workers include zinc and cadmium oxide, which are generated when iron pipes plated with these materials are heated. The very toxic effect of cadmium fumes, not generally known to the average shop worker, makes it imperative to supervise all use of cadmium-plated pipe very closely.

Conclusion

It should be apparent from the foregoing that any pharmaceutical industry, large or small, is particularly in need of expert counsel in matters affecting the health of workmen. A thorough knowledge of the literature of known poisons is essential for the industrial specialist in this field, but he must also have an alert readiness to detect and investigate possible new poisons. In doing so, the process of untangling the threads of a new syndrome from the inevitable surrounding mass of subjective symptoms, neurotic complaints, incidental diseases, and other irrelevancies requires the nicest judgment and scientific balance, together with a most intimate knowledge of all the manufacturing processes. Far as one may be from reaching this goal, the struggle towards it is full of interest and satisfaction.

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BOOK REVIEW

INDUSTRIAL TOXICOLOGY

By Alice Hamilton and R. T. Johnstone

(Oxford University Press, New York, 1945. 15*s*.)

This book is a reprint of a section of the Oxford Loose Leaf Medicine and has the same page numbers. Industrial toxicology is a knowledge of injurious actions of substances used in industry. Now, with rapid changes being made in the methods of industry, the importance of the subject has been greatly enhanced. This volume, therefore, is especially to be welcomed by general practitioners and specialist physicians, as well as by industrial medical officers. The book is divided into two parts; the first, entitled 'Pathology and Diagnosis' is by Alice Hamilton, and the second, 'Treatment and Prevention,' is by Rutherford T. Johnstone. There is an extensive bibliography with 264 references arranged alphabetically according to authors; excellent as this arrangement is, the bibliography would have been more useful if it had been divided into the different poisons or groups of poisons. The volume can be criticized principally for its omissions: for instance, no mention is made of manganese pneumonia, platinum asthma, or the latest reports on poisoning by beryllium tri-ortho cresyl phosphates, among other important industrial toxicological syndromes. Nevertheless this is a very good and well-written book, and can be recommended with confidence. It should find its way on to the bookshelf of every works medical officer. *K. M. A. P.*

BRITISH AND FOREIGN OFFICIAL PUBLICATIONS

ANNUAL REPORT OF THE CHIEF INSPECTOR OF FACTORIES FOR THE YEAR 1945

H.M. Stationery Office, London. Cmd. 6992. Pp. 104. Price 2s.

There was a fall in the total number of reportable accidents, particularly of fatal ones, compared with 1944. The estimated accident rate per 1,000 employed persons was the lowest since 1940, but it was still considerably higher than in pre-war years. This is attributed mainly to a lessening of incentive to remain at work after an injury. Accidents due to machinery were once again reduced, and there has been a real reduction in the accident rate for women. However, the rate for males under eighteen years was still disturbingly high, and for these juveniles careful initiation into factory life is advocated. Handling of goods accounted for the highest proportion of accidents (27·5 per cent.); next came accidents due to power-driven machinery (14·9 per cent.); and thirdly those due to persons falling (13·7 per cent.). Courses have been run for training of Safety Officers.

Advisory committees on working conditions already exist for the cotton, woollen, and jute industries. The Jute Committee has submitted its final report. Two new committees were set up during the year, one on working conditions in iron foundries and the other on the safeguarding of milling machines. In the Potteries emphasis was being laid on cleanliness, and more and more works were changing to low solubility or leadless glazes. Adequate heating of factories during the year was made difficult by fuel shortages, but ventilation improved with the removal of the blackout and anti-glare equipment. Earlier wartime relaxations of the regulations for hours of employment under the Factories Act, 1937, were reviewed, so that there was a general reduction in the hours worked by women and young persons.

In this report there are separate chapters on the work of the electrical, engineering, and chemical branches of the inspectorate. Electrical accidents were reduced in 1945, and there were thirteen cases in which prolonged artificial respiration saved life after unconsciousness from electric shock. The necessity for an efficient earth return in electric arc welding was not always recognized. Portable tools with flexible cables were responsible for a number of electrical accidents. The engineering section notes a number of explosions in pressure vessels, and was particularly concerned with ventilation and dust extraction problems and the guarding of power presses. A standing committee published a report on safety in the use of power presses. The senior chemical inspector reviews problems of dust and fume removal, escapes of gas, and entry of confined spaces where there are poisonous substances. As usual, explosions occurred from inflammable materials, organic dusts, and finely divided metal powders, particularly aluminium and magnesium. The latter should, ideally, be ground in a mixture of air and nitrogen.

Reviewing the war years, the senior medical inspector shows that, though the total number of cases of occupational diseases rose with the increase of industrial activity, the incidence of many of the preventable conditions was notably less than in the war of 1914–18. Though toxic jaundice was far less prevalent, cases of gassing from carbon monoxide and nitrous fumes were three times as numerous in the late war, though fatalities were fewer. In the war years there was a marked increase in notifications of epitheliomatous ulceration from gas and tar works.

The advisory panels on dermatology, ophthalmology, and radiology were active; of these, the last named was set up in 1945. They were concerned with such problems as safety in the luminizing industry and protection of the eyes from infra-red radiations of welding. Inflammation of the skin caused by radiant energy has now been scheduled for compensation. The medical branch of

the inspectorate has done research on such questions as the health of foundry workers and welders, trigger finger, the grinding of basic slag and card clothing, and exposure to chloroform and ether while working.

The position with regard to notifiable industrial diseases in 1945 is reviewed. There were forty-five cases of lead poisoning, which was a slight increase over 1944, though there were only two fatalities. Cases from accumulator works increased, but in other industries there was a fall, and no cases arose in either printing or pottery works. One case developed from casting of lead bronze. Tetraethyl lead poisoning was not seen. There were five cases of mercurial poisoning, one of which was from the manufacture of ethyl mercuric chloride, a fungicide; the man developed neurological signs and died. Only one man, who was working in a photogravure process, developed chronic benzene poisoning. There were six cases of toxic jaundice, and all were from working with T.N.T.; this was half the number for the previous year. Toxic anæmia was reported seven times from working with T.N.T. or benzene; there were two deaths. One case of compressed-air sickness occurred from long hours in a caisson. Seven cases of anthrax were notified, one fewer than in 1944, and there were for the first time no fatalities; treatment given was penicillin with either serum or an arsenical. For the first time no case occurred from handling wool.

Epitheliomatous ulceration was reported in 215 cases, eighty-three being due to pitch, ninety-three to tar, and thirty-six to mineral oil. Chrome ulceration was seen ninety-four times and occurred mainly in newer processes. There were no cases of phosphorus, arsenic, manganese, or carbon bisulphide poisoning notified.

Carbon monoxide was responsible for 218 cases of gassing, eighteen being fatal; these are much above the pre-war figures. Eighty-two were due to power gas, forty-two to coal gas, and thirty-seven to blast furnace gas. There were forty-seven cases of gassing by chlorine, and twenty-nine through nitrous fumes, mostly in nitrating processes. Narcosis due to trichlorethylene occurred fourteen times, particularly during cleaning out of degreasing tanks. Gassing due to nickel carbonyl was more than halved in 1945, but one case of iron carbonyl poisoning was reported. Methyl bromide poisoning occurred nine times, with three deaths. Dinitroorthocresol, a fungicide, caused two fatalities; poisoning is by inhalation of dust and fume or by skin absorption. Seven out of ten non-fatal cases occurred when a change was made from using a paste to grinding dry in the powder form.

Deaths from fibrosis of the lung in 1945 were 1,133, over a hundred more than in the previous year. This figure included eleven from asbestosis, ten from byssinosis, and 387 in coal miners. The voluntary system of reporting dermatitis yielded about 6,000 cases, which was but three-quarters of the previous year's total. "Copra itch" was noted; this may be an allergic response to mite-containing copra dust. Special examinations were made upon luminizers, industrial *x*-ray workers, and benzene and lead workers.

In 1945 there were 143 whole-time and 903 part-time works medical officers; since 1944 the former have decreased and the latter increased. The total number of factory canteens fell somewhat in 1945, owing to the closing of some of the larger works. There was, however, an increase in the number of canteens in small firms not legally bound to provide them. The evidence suggests that the workers will continue to use the many canteens that first started during the war. *J. N. Agate.*

LEGISLATION CONCERNING SAFETY AND HEALTH AT WORK (LEGISLACION SOBRE SEGURIDAD E HIGIENE DEL TRABAJO). 1946 Madrid: Ministry of Labour. No price given.

This book, a summary of the legislation in Spain relating to industrial safety and hygiene, is divided into four parts. In the first is a general review of existing legislation, and the other three parts deal with special fields—namely, accidents in agriculture, accidents at sea, and the insurance measures covering accidents in general. In the first part is given the scale of indemnity for various kinds of injury. In case of permanent incapacity or death the sum due is given to the victim or his relatives in the form of a pension. If it is shown that the accident occurred in a works in which the statutory safety precautions were neglected, then the compensation payable is increased. In certain kinds of industry it is obligatory to have medical or nursing aid available. Employers are obliged to insure against any claims which may be brought against them by employees. Penalties are laid down for neglect of certain precautions and failure to comply with regulations.

During the course of the war certain special regulations were drawn up in respect of the increased risks run by crews of ships at sea. These were supplementary to existing legislation covering maritime personnel.

The safety regulations for factories and work places follow those obtaining in most civilized countries. Reference is made to mechanical safeguards, to lighting and ventilation, sanitation, and general amenities. All important industries seem to be covered. There is an absolute prohibition of the employment of women and children in certain industries in which there is danger of poisoning, fire, or explosion. Nor may they work in certain industries with a risk of disease from inhalation of dust. In some of these the prohibition refers to certain processes only, and not to all. There are also regulations which prohibit young people from undertaking very heavy work in transportation, and delivery boys must not take loads over a certain weight. Night work is only allowed for women in certain circumstances; these have to be agreed by the local labour council, on which employers and workers are represented. In country districts children may not work in the fields during class time.

Forms of contract relating to the employment of apprentices and certain domestic workers are given. The inspectors of the Ministry of Labour have unrestricted access to all works at all times.

A government institute for industrial medicine, hygiene, and safety was founded by decree in July, 1944. This institute undertakes research work, advises employers, keeps statistics, and takes a special interest in medical work in industry.

Many undertakings are obliged to provide a canteen, with suitable protection from the weather and proper equipment. It is also laid down that those above a certain size must also make available for sale certain foodstuffs and other articles which the workers may need.

In the last part of this book there is a summary of the regulations relating to noxious or dangerous trades, the electrical industry, the manufacture of explosives, chemical works, and others. It would appear that a very comprehensive summary of existing regulations has been drawn up, and that these have been carefully drafted to cover most of the risks and hazards of industry.

G. C. Pether.

ABSTRACTS

(The abstracts are divided into the following sections: toxicology; industrial physiology; industrial lung disease; accidents and orthopaedic surgery; general. After each subsection of abstracts follows a list of any articles that may have been noted but not abstracted.)

TOXICOLOGY

Statistics of 100 Cases of Chronic Poisoning by Carbon Bisulphide. (L'intossicazione cronica da solfuro da carbonio. Una statistica di 100 casi.) VIGLIANI, E. C., (1946). *Med. Lavoro*, **37**, 165.

Carbon bisulphide is widely used in industry and its toxic manifestations have long been known. Owing to war-time conditions there was a large increase in the number of cases of carbon bisulphide poisoning in rayon factories in Italy, and in this article the author discusses 100 undoubted cases seen by him between 1938 and 1942. The commonest symptoms of carbon bisulphide poisoning are polyneuritis (88%), gastric disturbances (28%), headache, vertigo (18%), sexual weakness (16%), myopathy (15%), and tremors (15%). The first two are also the earliest to appear.

The polyneuritis never affected the trunk or the cranial nerves (except rarely the optic), and was most common in the lower limbs and always bilateral. Sensory disturbances took the form of paraesthesia and hypoaesthesia—never anaesthesia. There was marked loss of power in the limbs, with alteration in the reflexes, which were either weakened or absent though arm reflexes were never completely lost. In the author's opinion the most characteristic sign is a diminution or absence of the ankle-jerk, and he states that this sign, together with a marked loss of power, is never absent in true carbon bisulphide poisoning. Complete paralysis did not occur. A positive Lasègue's sign was exceptional. Figures of 80–90% for the incidence of psychotic manifestations used to be common, but in this series they only occurred in 6% of cases—probably owing to the more chronic character of the disease.

In 1944 Vigliani, Maspes, and Visintini (*Med. Lavoro*, 1944, **35**, 1) first described a myopathy associated with carbon bisulphide poisoning. This was noticed in 15% of this series of cases. There was a sensation of weight and rigidity in the legs, associated with hardening and contraction of the muscles. Hypertrophy of the muscle fibres occurred almost exclusively in the calf muscles. Gastric disturbances were among the earliest symptoms and consisted of flatulence, pyrosis, anorexia, and nausea.

Mild cases cleared up in from two to three months, others in from six to eight months. After one year complete cure was rare. Caution is always necessary, as even an apparently mild case may fail to clear up completely. Twelve cases in this series still had permanent disabilities in 1945–46. Treatment consisted of rest, strychnine, massage, and electrotherapy. Large doses of vitamin B were given in all cases. The author frankly states that he rarely obtained good results from vitamin therapy, but used it for lack of anything better and on account of its general tonic effects.

The concentration of carbon bisulphide in the atmosphere of the various departments of the factories was studied (using the methods suggested by the British Ministry of Labour) and was compared with the number and severity of cases occurring in each. These investigations showed that concentrations of 0·5 to 2·5 mg. per litre of carbon bisulphide could cause poisoning in a few months; concentrations of 0·2 to 0·35 mg. per litre rarely gave rise to poisoning, and then only very mildly; while concentrations of under 0·2 mg. per litre did not cause poisoning. The author considers that concentrations of 0·15 to 0·20 mg. per litre are the greatest that can be tolerated, and that those of 0·10 to 0·15 are safe.

[This is a most interesting article, with a number of case histories, and a full description of the use of carbon bisulphide in the rayon industry.] *G. W. Whittall.*

Haematuria Due to Picric Acid Poisoning at a Naval Anchorage in Japan. HARRIS, A. H., BINKLEY, O. F., and CHENOWETH, B. M. (1946). *Amer. J. publ. Hlth.*, **36**, 727.

On chance discovery of microscopical haematuria in 2 men, 245 others were examined and showed the same sign, and men from 25 out of the 28 ships in the anchorage were shown to be affected. No case was reported from ashore, but men from outside the area developed haematuria after boarding the ships and drinking the water. Specimens from ships in three other ports showed no abnormalities except in one unsubstantiated instance. An independent pathological examination confirmed the widespread haematuria at Wakayama, the port in question. Scale from a water pipe in one of the ships which had recently arrived showed picric acid, as did those specimens from ships already in the anchorage. It was normal practice for the ships to distil harbour water for drinking; after the tanks had been flushed there was a decline in the number of cases, and this in spite of the fact that some ships continued to distil harbour water. One man had gross haematuria, and 2 others had symptoms suggesting an acute nephritis; in the other cases the haematuria was trifling, though there was a large number of pus cells, which could not be explained. The effluent of local factories was not thought to be responsible, but 100 tons of picric acid for munitions had been dumped 15 miles away over a period of six weeks, and was carried by wind and tide. The fish locally were not affected. Harbour water, ship's drinking water, the scale of the evaporation, and scale from water pipes were all tested for aromatic nitrogen compounds and amines by a method outlined in the paper. Nitrogen compounds were found in the evaporator scale and water pipes, and in three samples of the drinking water. Picric acid would be expected to adhere to the scale, which is alkaline. Hydrochloric acid extracts were used, and picric acid was isolated from them by a method also outlined in this paper. Trinitrotoluene and trinitroaniline may have contributed to the haematuria, though

they would not have adhered long to the scale, nor have persisted long enough to be detected. The clinical findings concerning the outbreak were elicited by a questionary circulated to all ships. Haematuria was observed in the majority, but there were few other abnormalities. Centrifuged urinary sediments were examined from 711 men—almost 10% of the total population. Only 11 of them had microscopical haematuria, but the ships had ceased to use harbour water a few days before the arrival of the special pathological unit. In some urines the deposit showed an excess of pus cells, and a random sample showed the presence of picric acid. The picric acid must have been carried over in the stills in the vapour phase. It is concluded that there is a danger in dumping high explosive into water near anchorages. An activated charcoal or resin filter is suggested as a possible protective measure.

J. N. Agate.

Two Cases of Dimethyl-Sulphate Poisoning. (Due casi di intossicazione da solfato dimetilico.) BRINA, A. (1946). *Med. Lavaro*, **37**, 225.

A container of dimethyl sulphate fell on the floor early one morning and the clothes of two workmen were splashed with the liquid. No action was taken at the time, and it was not until the afternoon that both the men began to complain of photophobia, lacrimation, stabbing-pain in the eyes, irritation of the nasal mucosa, aphonia, and cough. Both showed intense reddening of the conjunctiva, palpebral oedema, epiphora, reddening and swelling of the fauces, and bronchitis. One had slight enlargement of the liver and urobilin in the urine. Both made an uninterrupted recovery in about 12 days. The author draws attention to the considerable delay in the appearance of symptoms, and infers that the chemical exerts its toxic action not as dimethyl-sulphate itself, but as a breakdown product, sulphuric acid. He also stresses the importance of care in handling this dangerous chemical.

Tom Rowntree.

Aniline Poisoning. (L'anilisme.) MERLEVEDE, E. (1946). *Rev. med. Louvain*, p. 309.

The wearing of shoes or gloves dyed with aniline can produce symptoms of acute and severe illness the cause of which may easily be overlooked by the physician. Five such cases seen by the author are briefly described, all of which were cured when the offending shoes were discarded. He also quotes a case reported to him of an infant poisoned by the vapour from a recently dyed leather jerkin that was drying in front of a fire.

The manufacture of aromatic hydrocarbons and their derivatives is attended by the risk of acute anilism. Three cases of severe industrial poisoning are recorded: one from aniline vapour, one from chloraniline, and one from warm aniline spurting on to the clothing. All recovered.

Aniline can penetrate the body by the respiratory, alimentary, or cutaneous route, the last being the commonest. It is excreted by the lungs, urine, and faeces. Acute intoxication varies from slight cases with headache, anorexia, nausea, possibly angina, and a just perceptible cyanosis, to the severe case with deep cyanosis, coma, and oliguria. Chronic intoxication may give any of a number of signs and symptoms, including secondary anaemia, persistent headache, dermatitis, hepatitis, asthma, cutaneous dysplasia, cystitis, or tumours of the bladder. In the treatment of severe acute intoxication the author recommends injection of nikethamide, bleeding, intravenous injection of 1% methylene-blue solution, and transfusion of blood in an amount rather less that that removed by bleeding.

H. E. Harding.

Poisoning by Phosphine. (Quelques considérations sur l'intoxication par l'hydrogéne phosphoré.) CLERENS, J. (1946). *Arch. belges Méd. soc.*, **4**, 201.

The industrial production of acetylene by the action of water on calcium carbide is accompanied by the formation of such impurities as phosphoretted hydrogen, sulphuretted hydrogen, arsine, and ammonia. Of these impurities it is probable that phosphine is produced in the greatest amount. This substance is known to be toxic, and processes in which it may be evolved are covered by various regulations. The author kept two pairs of white rats [of unstated age] in cages within the generating room of an industrial acetylene plant for 238 days, at the end of which period they were killed and examined. He estimates that during this period some 10%, or 65 cubic metres, of acetylene escaped into the room. When examined post mortem the animals appeared to be in a good condition. Histological examination showed hyperplasia of the thyroids of all the animals, some small areas of calcification in the muscles of the neck, and some slight inflammatory changes in the lungs.

[The cause of the thyroid hyperplasia is obscure: no details are given of the diet. There is no record of the composition of the atmosphere of the room.]

H. E. Harding.

Cases of Latent Benzol Poisoning. (Su alcuni casi di 'benzolismo latente.') CACCURI, S. (1946). *Rif. med.*, **60**, 416.

The writer describes cases of benzol poisoning in which the persons affected did not exhibit very conspicuous signs of their disorder. He suggests that it is precisely in these persons that greater interest should be taken, as they have not yet reached a dangerous or incurable stage and may readily be prevented from doing so. They use the term 'latent benzol poisoning' to describe a state in which, as shown by Weil, there are blood and marrow changes but no frank symptoms. The change from this early stage to a more advanced and dangerous one will occur insidiously. Reference is made to the increase in the ratio of conjugated to inorganic sulphate in the urine, this increase being rapidly lessened when exposure ceases.

The author examined 9 workers in a petroleum refinery. Some of these men were troubled by headache, pains in the limbs, and occasional bleeding from the gums; there were some changes in the blood picture. Several of the men complained of asthenia, and in some there was an unusually low blood pressure and changes in the heart sounds and the electrocardiograph, with frequent broadening and unevenness of the P wave.

Reference is made to the work of various authorities who have noted leucopenia with neutropenia, slight eosinophilia, and a reduction in the platelets. These changes may precede more grave manifestations by a considerable time. Purpura and haemorrhages may occur later on, and the early administration of vitamin C is a sound prophylactic measure. Although it is pointed out that the blood and marrow may apparently recover in 6 or 12 months after definite signs of poisoning have

been noted, cases are described in which, though exposure had ceased for some time, there was deterioration later, perhaps ending in death. The authors conclude with a plea for greater care in reducing the risk of exposure and emphasize the value of free periods with a change of work, which temporarily removes the employee from any contact with the poison. It is evident that the 'latent' condition cannot be very clearly defined.

G. C. Pether.

Oxygen Poisoning. X. The Effect of Oxygen at Eight Atmospheres upon the Oxygen Consumption of the Intact Mouse. STADIE, W. C., and HAUGAARD, N. (1946). *J. biol. Chem.*, **164**, 257.

In order to study oxygen poisoning, experiments were devised in which the oxygen uptake of the mouse could be measured at 8 atmospheres of oxygen A respirometer was used consisting of a glass cylinder 4 cm. in diameter and 15 cm. long. One end was constricted to a tube 3 mm. in diameter with a stop cock; the other end was closed with the ground-glass plate extending into a tube 3 mm. in diameter. Each end contained a canister of 'dioxorb' for the absorption of carbon dioxide. Space between the canisters was just large enough to contain a mouse. The tube at one end of the cylinder was connected to a source of 100% oxygen and the tube at the other end to a mercury manometer. The manometer had a two-way tap so that the respirometer chamber could either be connected to the manometer or to a source of 100% oxygen. When in use the respirometer was flushed with 100% oxygen and then connected to the manometer. Changes in mercury level in the manometer were measured. The volume of the free space in the respirometer chamber being known, the oxygen consumption of the mouse could be calculated from the changes in the mercury level. When the oxygen pressure was raised considerable amounts were absorbed by dioxorb. A reduction in the amount and an elevation of the pressure in two stages obviated this. Intact mice under 8 atmospheres oxygen pressure rapidly developed severe symptoms of oxygen poisoning without showing a measurable decrease of oxygen consumption. Xanthine oxidase, choline acetylase, and *d*-amino acid oxidase in homogenized tissue extracts are rapidly inactivated at high oxygen pressures, but the two latter are quite unaffected when their activities are measured in intact tissues.

It is concluded that hyperoxic anoxia is not the cause of the acute phase of oxygen poisoning, which occurs some time before the possible inactivation of any enzyme system.

J. Dawson.

Oxygen Poisoning. XI. The Relation between Inactivation of Enzymes by Oxygen and Essential Sulfhydryl Groups. HAUGAARD, N. (1946). *J. biol. Chem.*, **164**, 265.

The toxic effects of oxygen at high pressure may in part at least be due to the inactivation of certain enzymes. With the exception of cholinesterase all enzymes which contain sulphydryl groups are inactivated by exposure to seven atmospheres of oxygen at 38° C. for 2 to 4 hours. The rate of inactivation, however, is slow. When contained in the intact cell certain enzymes, such as *d*-amino-acid oxidase and choline acetylase, are resistant to oxygen, but they are inactivated in tissue extracts. Phosphorylation of glucose in kidney extract is not readily affected by oxygen at high pressure, which indicates that phosphorylating enzymes are not particularly susceptible to oxygen. The symptoms of oxygen poisoning in the intact animal may be due to oxidation of enzymes containing sulphydryl groups. *J. Dawson.*

Noxious Vapours in Aircraft Cabins. SPEERT, H. (1946). *Occup. Med.*, **2**, 101.

The toxic effects that may arise in aircraft cabins are due to fumes of aviation spirit, penetration of exhaust gases, leaks from the hydraulic line—which contains a mixture of compounds with varying toxic properties—and entry of toxic decomposition products of the cooling fluid in liquid-cooled engines and of escaping oil coming into contact with hot engine parts.

Aviation spirit contains aliphatic and aromatic hydrocarbons, tetra-ethyl lead, and an aromatic amine, which may be xylidine. Petrol is heavier than air and is readily absorbed from the lungs. If inhaled for more than a few minutes, one-tenth of the explosive petrol-air concentration is sufficient to cause such symptoms in man as dizziness, nausea, or headache. Higher concentrations lead to sensory symptoms, anaesthesia, and loss of consciousness. The higher the concentration, the more rapid the absorption and the onset of effects due to the irritant and lipolytic properties of the hydrocarbons. Acute toxic action includes a burning sensation in the eyes with lacrimation, visual disturbance, abnormalities of speech and hearing, disorientation, restlessness, euphoria, convulsions, coma, and death. According to Machle (*J. Amer. med. Ass.*, 1941, **117**, 1946) the maximum tolerable concentration of ordinary petrol is about 500 parts per million, but aviation spirit is probably twice as toxic. The danger is enhanced by the need in airmen for a high degree of mental alertness. Poisoning by tetra-ethyl lead in aircraft is not met with. Toxic effects due to the presence of the aromatic amine are unlikely. Aviation spirit contains 3% xylidine (U.S.A.). The additional dangers of fire and explosion are well known. The author details a routine to be followed if a leak is detected in the aircraft: no smoking; electrical switches to be left alone; aircraft to be ventilated; oxygen masks to be worn; goggles to be put on; sleeves to be rolled down, and other articles such as helmets and gloves to be worn to cover the body in case of fire; oxygen and artificial respiration to be given as required.

Carbon monoxide is the most important of the exhaust gases, and may constitute nearly 9% of these at the take-off, and 3% while in flight. It is also formed when guns and cannon are fired. Detectors showing a red light at 0·005% have been employed. It seems best to use the concentration of carbon monoxide in the blood as an index of contamination. Smokers may normally have 7–8% saturation. The main symptoms, in order of frequency, due to carbon monoxide are headache, weakness, vertigo, nervousness, dyspnoea, paraesthesiae, muscular twitching, emotional disturbances, nausea, drowsiness, unsteady gait, neuromuscular and joint pain, tremor, muscle cramp, coughing, sweating, vomiting, anorexia, precordial distress, vasomotor instability, perversion of taste and smell, impairment of speech and hearing, hoarseness, and yawning. Eye affections are diplopia, amblyopia, contraction of fields, anisocoria, retinal oedema, and neuroretinitis. Visual discrimination is much affected by even small blood concentrations of carbon monoxide. Arterial oxygen saturation at 14,000 ft. is 80%; when the blood is in equilibrium with air containing 0·01% carbon monoxide this saturation is reached at only 7,000 ft., so that the safe ceiling is greatly diminished by the presence of carbon monoxide.

The most significant of the oxides of nitrogen in exhaust gases is nitrogen dioxide: this is converted to nitrous and nitric acid in the body. It is suggested that these latter may cause the irritation of mucous membranes and upper respiratory tract. The maximum permissible concentration of nitrogen dioxide in air for several hours' exposure at sea level is given as 0·0025%. A hydraulic fluid commonly used contains castor oil, propylene glycol, octyl and iso-amyl alcohols, phosphoric acid, cresylic acid, and an aliphatic amine. Poisoning by some of these compounds can arise from a small leak in the hydraulic line. More recently a different type of hydraulic fluid of relatively low volatility and low toxicity, has been introduced. Cooling liquids of the ethylene glycol variety can give rise to toxic aldehydes when, as a result of a break in the lines, the glycol is decomposed by the overheated engine or by contact with hot metal parts, with evolution of smoke. Oil leaks are fairly common in aircraft, and the contact with hot engine parts results in smoke, which often finds its way into the cockpit. Various toxic aldehydes are formed, which can give rise to symptoms similar to those of carbon monoxide The author describes 12 cases illustrating toxic events referable to the above causes. *M. W. Goldblatt.*

Two Cases of Polyneuritis due to Lead Poisoning. (Deux cas de polynévrite Saturnine.) WOLINETZ, E. (1946). *Paris méd.*, **36**, 486.

Methyl Alcohol Poisoning. (Metanolforgiftning.) SINDING-LARSEN, M. (1946). *Tidsskr. norske Laegeforen.*, **66**, 639.

INDUSTRIAL PHYSIOLOGY

Studies on Altitude Tolerance. 1. Studies on Normal Rats—Effect of Repeated Short Exposures to Reduced Atmospheric Pressure. THORN, G. W., CLINTON, M., FARBER, S., and EDMONDS, H. W. (1946). *Bull. Johns Hopk. Hosp.*, **79**, 59.

Rats repeatedly exposed for a short period each day to moderate reduction of pressure are generally able to withstand an exposure to an extreme reduction at which normal, unconditioned animals fail to survive. The number of conditioning exposures exerted a greater effect on survival rate during an acute 'altitude-survival test' than the actual altitude at which conditioning was carried out, provided the altitude used for conditioning was sufficient to produce any appreciable effect.

The altitude-survival test consisted in determining the survival rate of groups of animals during a single 2-hour exposure to a reduced atmospheric pressure sufficient to cause death in at least 50% of the control animals. It was carried out at a pressure equivalent to an altitude of 34,000 ft., the conditioning by a daily 2-hour exposure to 12,000, 18,000, or 26,000 ft. for 7 or 30 days. Unconditioned animals did not as a rule survive, neither did animals conditioned to 12,000 ft. Seven conditioning exposures to 18,000 or 26,000 ft. resulted in a survival rate of 20%, whereas 30 conditioning exposures at 18,000 and 26,000 ft. caused a survival rate of 70 and 80%. The critical level for conditioning seems to be 18,000 ft.—a relatively low altitude considering the natural tolerance of the Sprague-Rawley strain of rat used and their average weight of 200 g. When conditioned 80 to 90% of rats survived a 2-hour exposure to 29,000 ft. Conditioning caused no significant alteration in organ weights or in the morphology of thymus, adrenals, or heart. No relation could be found between increased survival rate and haematocrit values. Exposure to 26,000 ft. for 2-hourly periods for 30 days produced renal lesions with deposits of calcium in the collecting tubules. These deposits may be due to alkalosis from carbon dioxide loss caused by the hyperventilation resulting from anoxia at 26,000 ft. There is no clear evidence about what is actually involved in conditioning to high altitudes. *E. M. Fraenkel.*

Studies on Altitude Tolerance. 2. Studies on Normal Human Subjects—Effect of Repeated Short Exposures to Reduced Atmospheric Pressure. CLINTON, M., THORN, G. W., and DAVENPORT, V. D. (1946). *Bull. Johns Hopk. Hosp.*, **79**, 70.

Young men aged 21 to 32 years, who had been carefully examined and found free from organic disease, were used for the tests. A group of these were conditioned for the 'high altitude tolerance test' by previous periods of 2 to 4 weeks' exposure to pressures equivalent to 12,000 ft. of altitude for 3 hours daily. Some of the men were kept on a restricted constant diet in the metabolic ward, others on an unrestricted diet. The conditioning took place in a special decompression chamber with a ventilating rate of 600 cu. ft. per minute at a temperature of 20° C. and at a decompression rate equivalent to 3,000–4,000 ft. per minute, recompression being carried out at a slower rate of 1,500–2,000 ft. per minute. The 'altitude tolerance test' was done under strictly basal conditions after a night in the metabolic ward. The subject started breathing from a gasometer with fresh air, the test began with rebreathing (Schneider test) into it when the air volume was 50 litres. The oxygen content of the air remaining in the spirometer was analysed in a Haldane gas analyser and determined in percentages of oxygen (altitude equivalent) and carbon dioxide. Light signals were used as tests, and failure to respond to these was considered as the end-point. Complete inability to respond usually followed a period of less than 1 to 2 minutes of erroneous or delayed response. In 10 out of 11 subjects improvement in 'altitude tolerance' was observed during the second to fourth week of daily exposures to 12,000 ft. Improvement was characterized by a lower content of oxygen in the spirometer at the end of the test, by an increase in time before the subject failed to respond to the lights, and by a slower pulse rate through the greater part of the test. This was, however, fairly constant at the end of the test in the same person. Improvement was not accompanied by an increase in the red cell count, haemoglobin value, or cardiac size. Nitrogen and phosphorus were retained during the periods of exposure, but apart from that no significant metabolic change occurred. Little was revealed about changes in the adrenal cortical function. No evidence of chronic altitude sickness was observed in any of the subjects. One subject developed premature auricular contractions in the evening of the day of his twelfth exposure and was withdrawn from the experiment. The single subject who failed to show improvement after repeated exposures came from a high plateau in the south-west of the United States.

It appears unlikely that the 'ceiling' of aviators in high-altitude flying of 30,000 ft. or over, with supplementary oxygen given, would be improved by daily exposures to a pressure reduced to the equivalent of 12,000 ft.

In the rehabilitation of aviators who have been grounded a course of preliminary exposures may be extremely beneficial, both in improving the individual's tolerance and as an indication whether he is physically able to resume flying.

[The presence of a higher content of carbon dioxide remaining in the spirometer during the test may produce conditions different from those at high altitudes.]
E. M. Fraenkel.

The Respiratory Metabolism of Human Subjects during Prolonged Exposures to Simulated Altitudes of 8,000 and 12,000 feet. D'ANGELO, S. A. (1946). *Amer. J. Physiol.*, **146**, 710.

Exposure for 10 hours to pressures equivalent to 8,000 and 10,000 ft., without added oxygen, increased the depth of respiration of resting subjects and caused alkalosis. The physiological changes were reflected in the behaviour of the subjects, who showed somnolence, irritability, inattention, lack of volition, and fatigue. There were obvious differences in these respects between individuals. Resistance to exposure (judged by these symptoms) was best correlated with elevation of the respiratory quotient, those subjects who showed little or no elevation tolerating the altitude poorly. There was no significant difference between the results of exposure to 8,000 and 10,000 ft., and the advisability of giving extra oxygen, even at a height as low as 8,000 ft., is suggested.
Raymond Greene.

A Disease Resulting from the Use of Pneumatic Tools. PETERS, F. M. (1946). *Occup. Med.*, **2**, 55.

Raynaud's phenomenon has for years been seen in those who use vibrating tools, of which hundreds of varieties are marketed. A short review of the literature shows that vibration is the primary cause of the lesions, that the critical vibratory rate may be 2,000–3,000 per minute, and that the effects noted are: (1) disturbances in blood vessels, resembling Raynaud's phenomenon or Buerger's disease; (2) affections of muscles, with atrophy; and (3) injuries to bones and joints.

In the present investigation the tool was driven by a compressed-air turbine at 25,000 r.p.m., the cold exhaust air sometimes passing over the worker's hands. The work was burring of aluminium alloy castings. The vibration amplitude was estimated at 0·001–0·002 in. (0·025–0·056 mm.). Out of 1,000 workers, 116 presented symptoms, the dominant hand being affected, and the onset being from 1 to 72 weeks after starting work with the tool, with a mean of 19 weeks. The complaints were of continuous burning pain in the hand, with stiffness and weakness when fine movements were attempted, and swelling. No vascular changes were obvious. There was sensory loss in areas in contact with the tool, limitation of finger movements, and trophic skin changes. Oscillometric readings for the limbs were normal, and digital plethysmography was equivocal. Skin temperatures were in most cases lower on the affected side by an average of 2·6° C. The capillary blood flow in the nail bed was observed, and photomicrographs and drawings were made. The capillary loops were small and of abnormal shape, with a sluggish flow. Illustrations are given.

The various treatments tried—physiotherapy, artificial pyrexia, prostigmin (neostigmine), nicotinic acid, and thiamine hydrochloride—had little effect. Improvement was slight even when patients with mild symptoms had stopped working for a year. Prophylactic measures proposed are: limitation of vibrations to below 2,000 per minute, damping of vibrations, curtailment of time of using the tool, and devices to hold it. Destruction of capillaries by repetitive trauma is suggested as being the mechanism involved.

[It is to be noted that the capillaries actually observed were not themselves subject to direct trauma, and that the prophylactic measures suggested are scarcely practicable.]
J. N. Agate.

Salt and Glucose Loss during Work. (La pérdida de sal y glucógene en el trabajo.) DEFELICE, V. (1946). *Bol. Segur. Hig. Trab.*, **7**, 10.

INDUSTRIAL LUNG DISEASE

Latent Silicosis and Tuberculosis. DAYMAN, H. (1946.) *Amer. Rev. Tuberc.*, **53**, 554.

That the inhalation of fine silica dust predisposes the lungs to entertain tubercle bacilli is accepted. Exactly how this comes about and how much dust is required for the purpose is not known. Whether it arises from the chemical nature of the dust or the physical changes it sets up in the lungs remains undecided. Four fatal cases are now reported in which there was slight occupational exposure to silica or asbestos dust, but in which the patients, when first seen, were not considered to have silicosis of clinical significance. However, tuberculosis, when it developed, progressed rapidly and was associated with the precipitation of a silicotic fibrosis. The concomitant advance of these two pathological conditions has often been observed; either factor seems to activate the other. A survey of 77 patients with both silicosis and tuberculosis showed no correlation between the size or number of the silicotic nodules determined radiographically and the rapidity with which death from tuberculosis occurred.

[The occupational history in these cases suggests that the dust exposure may have been considerable, even though rather short, and that plenty of dust may have gained access to the lungs ready to precipitate a silicotic condition.]
E. L. Collis.

Coexistent Pulmonary Asbestosis and Sarcoidosis. SKAVLEM, J. H., and RITTERHOFF, R. J. (1946). *Amer. J. Path.*, **22**, 493.

In spite of the wide use of asbestos, only 19,700 persons were employed in 1944 in the United States in the asbestos industry. Though Fahr described the first case of pulmonary asbestosis in 1914, interest in the disease dates from Cooke and McDonald's report of a case in 1927. Since then approximately 150 necropsies have been recorded. Reports of necropsies on cases of sarcoidosis are even rarer, only 58 being on record. The two diseases present many clinical and radiographic similarities: their fatal complications, tuberculosis, and heart failure, are alike.

A white man, age 42, noticed progressive nocturnal dyspnoea and loss of weight. He had worked in an asbestos plant for twenty-five years but was exposed to a slight dust hazard. Clinical examination of the chest was unequivocal: no signs of cyanosis, clubbing, or heart failure were noticed. Radiographic examination disclosed numerous small nodular opacities scattered throughout the lung field. Eleven months later the patient died from respiratory failure. Post-mortem examination disclosed innumerable slightly raised greyish-green nodules, 1 to 2 mm. in diameter, throughout the lung. Thin fibrous bands connected the nodules. Emphysema was present, the pleura and interlobal septum were thickened, and there was saccular and cylindrical dilatation of the bronchi lined by white,

glistening mucosa. The tracheo-bronchial lymph glands were moderately enlarged, and on section consisted of dense, rubbery, anthracotic centres with a thin, yellowish-white periphery. Microscopically, linear interlacing fibrosis, especially prominent in the subpleural areas, was found. Innumerable nodules were present in the fibrotic area: generally, nodules were of two types: sarcoidal, and foreign-body granuloma. The former were clearly demarcated and free from caseation, and they contained frequent giant cells of two types (a) foreign-body, (b) Langhan's cells, with an ' asteroid ' eosinophilic body in large intracellular vacuole. More often the Langhan's cells contained an oval or budding body suggestive of Schaumann's intracytoplasmic inclusion bodies. Foreign-body granuloma were less well defined and consisted of irregular monocytes with one or more foreign-body giant cells. Asbestos bodies were present. In some areas the two types of nodules were mixed. Section of the tracheo-bronchial glands showed almost complete replacement of the lymphoid tissue by sarcoidal nodules. Chemical analysis of the lungs was consistent with the presence of asbestos.

In view of the exposure to asbestos, the possibility of sarcoidosis was not considered in diagnosis, though in retrospect it was felt that the rapidly increasing dyspnoea unaccompanied by right-sided heart failure should have aroused suspicion of a concomitant pulmonary lesion. No collateral evidence of sarcoidosis (such as biopsy of a lymph node or skin lesion) was available. Asbestosis of the degree shown by *x*-ray examination would not alone have caused death. Since the majority of sarcoidal nodules were without fibrosis, it seems that the sarcoidosis was grafted as a pre-existing asbestosis. Further, the marked peribronchial fibrosis with sequestrated asbestos bodies, and the marked pleural fibrosis and metaplasia of the bronchial epithelium, suggested that the asbestosis was more than 700 to 800 days old. All the Schaumann bodies (present in 4% of the giant cells) gave a strong reaction to iron, and a doubly refracting non-lipoid substance was present in the giant cells in close relation to the Schaumann bodies. Stellate bodies (called asteroid bodies by Friedman), perhaps better termed ' Wolbach's asteroids,' were present in 1% of the giant cells and have not before been reported in an association with Schaumann's bodies. Definite transition stages in the formation of the asteroids were seen. No transition stages between ' Wolbach's asteroids ' and Schaumann's bodies were even remotely suggested.

The pathological relationship between asbestosis and sarcoidosis depends on the chronological development of the lesions: the localization of sarcoidal tubercles in the asbestosis zones suggest an analogy between the intimate relationship of tubercle and the pneumoconioses. This is possible whether sarcoidosis is considered to be irreconcilable with tuberculosis, or whether sarcoidosis is regarded as a special form of tuberculosis, when the case would be one of asbestosis with superimposed non-caseating tuberculosis.

Excellent photographs and microphotographs illustrate this paper. *T. A. Lloyd Davies.*

A Mass Chest X-Ray Survey in Philadelphia War Industries. ELKIN, W. F., IRWIN, M. A., and KURTZHALZ, C. (1946). *Amer. Rev. Tuberc.*, **53.**

Mass radiography is being so extensively carried out in the United States that by May, 1945, 109,703 persons had been examined in 17 surveys. The findings are now presented on 71,767 persons employed in a navy yard, an arsenal, and a signal depot, all of whom were at work when they underwent *x*-ray examination. Each diagnosis of respiratory trouble was confirmed by more complete investigation; other abnormalities, such as cardiovascular lesions, were detected by gross readings of films. Over all 1,633, or 2·3% were classified as having radiographic evidence of reinfection tuberculosis; 85 cases were far advanced, and 353 moderately. The percentage of cases of tuberculosis among white persons was 2·4, and among non-white persons 1·9. As the mortality from tuberculosis is far higher among negroes than among white persons, this finding is unexpected; it may be that the more exudative response of the negro to the tubercle bacillus renders him too ill when he has active disease to be at work. The median age of those with reinfection tuberculosis was 44 years, while the median age of all those examined was 31 years. The incidence of tuberculosis thus found steadily increased with age from 0·6% at ages 15 to 19 to 8·1% at ages 65 and over; this steady increase was independent of both sex and race. It agrees with recent tuberculosis mortality among white males, but not with such mortality among negroes. No preponderance was found of any stage of severity in any age group. Cardiovascular abnormalities numbered 1,409, or 2·0%, and, of these, widened aorta claimed 644, while 598 were ascribed to heart disease as evidenced by alteration in size or shape of the heart shadow.

E. L. Collis.

The Utilization of Aluminium—In the Prevention and Treatment of Silicosis. HANNON, J. W. G. (1946). *Industr. Med.*, **15,** 527.

The development of aluminium as a therapeutic agent and the mode of action of silica are reviewed. Aluminium inhalation in the treatment of 46 ceramic workers suffering from silicosis resulted in subjective improvement in 78% ; of these 80% showed an improvement of 20% in pulmonary function.

[The statistical data are too incomplete and vague to be of significance.] *T. A. Lloyd Davies.*

Legal Controversies concerning Cases of Silicosis in the Province of Milan before the Introduction of Compulsory Insurance. (Considerazioni sui casi di silicosi oggetto di controversie giudiziarie nella provincia di Milano prima dell'assicurazione obbligatoria.) PARMEGGIANI, L. (1946). *Med. Lavoro*, **37,** 249.

Some Aspects of Silicosis in Switzerland. (Quelques aspects de la silicosis en Suisse.) THOMAS, A. (1947). *Rev. méd. Liège*, **2,** 147.

The Heart in Pulmonary Silicosis. (La cœur dans la silicose pulmonaire.) MARTIN, E., ROCHE, L., and ODE, L. (1947). *J. Méd. Lyon*, **654,** 249.

Silicosis According to the Investigations of Leroy U. Gardner. (La silicose d'après l'œuvre de Leroy U. Gardner.) ROCHE, M. L. (1947). *J. Méd. Lyon*, **654,** 235.

Initial Stages of Porcelain Silicosis. (Om porcellænssilikosens Begyndelsesstadier.) ESKILDSEN, P., and FLEMMING MOLLER, P. (1947). *Ugeskr. Læg.*, **109,** 219.

Tuberculous Pneumoconioses. (Sur le problème des tuberculo-pneumoconioses.) COURTOIS, R. (1947). *Poumon*, **3,** 65.

ACCIDENTS AND ORTHOPAEDIC SURGERY

Special Characteristics and Requirements of Orthopaedic Surgery in Industrial Patients. TEECE, L. G. (1946). *Med. J. Austral.*, **2**, 580.

The author describes the problems which arise in treating industrial injuries in New South Wales, where the Workers' Compensation Act has been in operation for 20 years, and draws attention to the increasing frequency with which employers and insurance companies seek specialist opinion and treatment for injured workmen.

In discussing the treatment of some of the more common industrial injuries he emphasizes the need for a conservative outlook. In the hand the object of primary treatment should be to save as much as possible of every digit: the question of amputation can be considered at a later date when the functional importance of the stiff finger can be more accurately assessed. The treatment of the ununited fracture of the scaphoid is a common industrial problem, and the author mentions the frequency with which this fracture is accidentally discovered in patients who had been unaware of its presence and had suffered no serious disability. As a general rule no special treatment is required for non-union of the scaphoid in a workman in whom the disability may be trifling and who may not be prevented from returning to useful employment or even to heavy work. When surgical treatment is required, the author favours the use of a bone screw followed by prolonged immobilization.

In discussing the treatment of back injuries the author questions the wisdom of advising operation for intervertebral disc injury in a workman who has to perform hard manual labour. The article concludes with a note on the difficulty of deciding what constitutes aggravation of pre-existing disabilities, such as flat feet or loose bodies in joints. *J. S. Batchelor.*

Rapid Rehabilitation Following Hand Injuries. LEFKOE, H. (1946). *Arch. phys. Med.*, **27**, 499.

The author deplores the lack of recognition of the value of physiotherapy in the rehabilitation of hand injuries (which, he points out, cause 77–79% of all permanent disabilities in the field of industry), and opposes the thesis that ordinary use alone of the recovering hand is more valuable than so-called physiotherapy. Active use of the hand will improve function but not to a maximum, since the patient replaces the action of muscles by trick movements; therefore the aim in the early stages should not be the quickest possible return of the patient to work, but the maximum recovery of absolutely normal function, and this should be achieved through constant supervision and exhortation by the physiotherapist. Later, if the duration of disability brings adverse economic factors seriously into play, return to work may have to supplant this ideal aim. A number of factors making for shorter periods of disability are reviewed. Inability to perform active movements may be as important as infection in causing joint stiffness. Early movements after tendon operations, early skin-grafting for burns followed by early movements, skin-grafting for traumatic amputation of fingers, all make for rapid recovery of power to perform active movements. Continuous immobilization, where necessary, must not include joints which need not be immobilized, and the author believes that in such instances as capsulotomy of an interphalangeal joint or fracture of the terminal phalanx it need only be kept up until the immediate soft-tissue reaction has subsided; he warns against pre-occupation, in fractures, with the anatomical result as seen in the radiograph. Where pain exerts an excessive inhibitory action he recommends the use intravenously of 20 c. cm. of 0·1% aqueous procaine hydrochloride as an analgesic, not to permit forcible manipulation but to allow the patient to co-operate in and initiate active movements. He pleads for frank admission by the physiotherapist that progress has ceased, so that further surgical measures can be carried out without delay.

In tendon transplants the best results are obtained when the muscle transplanted is of good power. Exactly controlled electrical stimulation of the newly transplanted muscle can maintain this power while voluntary contraction is re-established. When voluntary power is completely inhibited it may be suddenly restarted after the use of the muscle as a synergist in the opposite type of action—e.g. wrist extensors inhibited by mental alienation after prolonged inactivity may act voluntarily after the patient sees them work involuntarily when he makes a fist. In those patients with constitutional neurovascular inferiority who are subject to severe traumatic oedema after minor injuries the author has found injection of the stellate ganglion with procaine a useful procedure; also radiotherapy, given with the idea of causing rapid fibrosis of young connective tissue, is useful in limiting stiffness from chronic periarticular thickening after sprains. *O. J. Vaughan Jackson.*

Metatarsal Fractures. MORRISSEY, E. J. (1946). *J. Bone Jt. Surg.*, **28**, 594.

Foot trauma is probably one of the most frequent causes of loss of man-hours in industry. This paper is a description of a new type of treatment designed to lessen the period of disability in cases of metatarsal fractures. Treatment consists of the application to the foot of a simple stock-moulded leather arch, with a sponge-rubber metatarsal pad added in some cases, the foot being strapped in a neutral position. Active weight-bearing is started immediately or within a few days of the injury and early return to work is possible. The functional end-results in a series of 61 cases were excellent. *A. M. A. Moore.*

Lumbago and Sciatica as Industrial Accidents. (Lumbago y ciática como accidentes del trabajo.) BARD, L. (1947). *Medicina Méx.*, **26**, 47.

GENERAL

Longevity at Record High in Industrial Population. (1946.) *Statist. Bull. Metrop. Life Insur. Co.*, **27**, 1.

The expectation of life at birth in 1945 among industrial policy holders of the Metropolitan Life Insurance Company of the U.S.A. had increased by 1½ years since 1941 and by half a year since 1944. The upward trend toward longevity since 1879–89, when the expectation of life at birth was 34·00, has thus continued during wartime and is now 64·95. In 1919–20 it was 51·14, and in 1930 it was 57·36. There has been a gain of 18·32 years since 1911–12. The *Bulletin* considers full employment at high wages and the use of sulphonamides and penicillin to be the main factors in this wartime rise.

The gains in expectation of life were not equally shared between the two sexes, women making the better showing —coloured women better than white. White women

showed remarkably low mortalities in the second decade of life, while coloured women had double or treble the mortalities of white women at the ages of 10 and 15. These sex and colour differences reached a maximum at the age of 20, when, in 1945, male mortality (exclusive of deaths from enemy action) was $3\frac{1}{3}$ times the female mortality, and coloured female mortality was $3\frac{5}{8}$ times the white female mortality. Up to middle life or later, coloured people had a lower expectation of life and a higher mortality rate in each sex than white people, but at the age of 65 the expectation of life was higher in coloured men than in white men, and at 75 the same was true of coloured women. *C. O. Stallybrass.*

Central Mining—Rand Mines Group. Health Department. Report for the Year 1945. Pp. 1–15 and Map. 2 figs.

In the report of the Health Department of the Central Mining—Rand Mines Group for 1945, the following points are of interest. Absenteeism increased slightly, as it has done each year, in spite of a decrease in the number of shifts lost due to accidents. Parallel with this there was a rise in disease incidence, with an increase in deaths from pneumonia, tuberculosis, and influenza.

The death rate for pneumonia was 0·86 per 1,000, the highest since the introduction of sulphonamides, while the death rate for pulmonary tuberculosis has doubled since 1942. While the number of fresh cases of silicosis was low (53), the case mortality rate rose substantially. Influenza incidence has increased steadily each year, probably a cyclical phenomenon. There were 26 cases of meningococcal meningitis without a death, and 34 cases of other forms of meningitis, with a record low case mortality rate (penicillin and sulphonamide therapy were used in most of these cases). The incidence of enteric fevers has been the lowest on record, although, as usual, the case mortality was high. Six cases of scurvy occurred. There was an increase in the incidence of malignant tumours, an increase apparently general in the Bantu races. The report states that it is difficult to escape the conclusion that the rise in incidence of disease, and particularly of respiratory disease, was related to the food shortages. The meat ration fell far below the minimum laid down by the Government ration scale, and the amount of first-class protein and animal fat was insufficient for men doing hard manual labour.

S. S. B. Gilder.

Occupational Diseases in Government-Owned Ordnance Explosive Plants: Observations on their Prevalence and Control during World War II. McConnell, W. J., Flinn, R. H., and Brandt, A. D. (1946). *Occupat. Med.*, **1**, 551.

This is a most painstaking collection of statistics about the incidence of occupational disease in U.S. Government factories making explosives; but the figures are so immense that the reader is swamped by the generality of the tables. The report occupies sixty-seven pages, with numerous tables and graphs which it is impossible to reduce to a clear summary. One hundred and one factories employed on an average 309,000 persons on various jobs during the period of observation, from February, 1943, to April, 1945: 968,000 man-years were worked, with only 22 fatalities from TNT, 3 fatalities from nitrogen oxides, 2 fatalities from carbon tetrachloride, and 1 from ethyl ether. Only 6 fatalities occurred in the last eighteen months of war. The authors emphasize the latent period between the inhalation of nitrogen oxides and the occurrence of pulmonary symptoms—a delay which, if not recognized so that the patient may be treated appropriately, may cause loss of life through pulmonary oedema. Undoubtedly this is a fine record; in addition, control measures exerted a marked influence on the incidence of non-lethal toxic effects. Dermatitis was the most serious toxic manifestation, especially with TNT and tetryl. Transfers to alternative work dropped the peak of 44 per thousand man-years to 22·5 at the end of the period in spite of a great increase in production. It is clear from this report that industrial medicine pays: yet below the surface the report leaves a feeling that all was not well. In some plants the annual labour turnover was 100% or over. The Americans are to be congratulated on publishing such a widespread survey so quickly after the end of the war, and at least U.S. statistics are not bogged in official reticence. The report should be a stimulus to the British authorities to publish a similar account—and, perhaps, to improve on the American report by including a judicious mixture of clinical medicine.

T. A. Lloyd Davies.

Medical Supervision in Factories. Doig, A. T. (1946). *Prescriber*, **40**, 176.

Although the welfare movement began over 100 years ago, it has only during the present century received due recognition. The two world wars have stimulated it. The first Factories Act, 1833, gave very limited powers. These have been extended by legislation, the last measure passed being the Act of 1937. The Factory Department of the Home Office recommends voluntary schemes for medical inspection of employees, subject to special risks such as tar distilling. Professional secrecy should be observed, but discovery of industrial diseases must be disclosed to the occupier of the factory.

Apart from certain Government-owned concerns, such as the General Post Office, there were probably no full-time industrial medical officers before 1923. In 1944 there were 180 doctors working full time in 275 factories. The main duties of factory medical officers are the provision of first aid for injury or sickness, medical examinations on request, initial and periodical examinations of persons at special risk, 'fit for work' examinations, advice to management on factory hygiene, liaison with outside medical officers, health education and keeping (confidential) records. Comparison is made between the work of the factory doctor and that of the medical officer of health, the main difference being their respective fields of operation. Some employers criticize medical supervision on the ground that it should be provided through the general practitioner. The fact is overlooked that many insidious diseases are detected at routine inspections which take place during working time, the symptoms probably not being considered important enough by the victims for them to trouble the doctor during leisure hours. Workers have suggested that the factory doctor is the 'employers' man' and therefore biased. The success of the doctor depends on his having the confidence of both sides. Full co-operation with his professional colleagues must be maintained. The British Medical Association code of ethical rules for industrial medical officers should be studied by those engaged in this work.

Since the introduction of adequate medical schemes the incidence of industrial disease has diminished, sickness absences have lessened, and a happier attitude of workers has been promoted. It is emphasized that the

doctor should be familiar with the conditions under which the employees work; he should not be content with sitting in the ambulance room. *Cecil Herington.*

The Application of Dust-Laying Oil to Cotton. BAYLEY, C. H., ROSE, G. R. F., and WEATHERBURN, A. S. (1946). *Canad. J. Res.*, **24**, sect. F, 348.

The authors have studied the technical problems concerned in the application of dust-laying oils to textiles for the combating of dust-borne infection. The oiling of woollen fabrics was previously discussed (Bayley and Weatherburn, *Canad. J. Res.*, F, 1945, **23**, 402): this paper records observations made on the oiling of cotton fabrics. The work is based on the method of Harwood, Powney, and Edwards (*Brit. med. J.*, 1944, **1**, 615), in which the fabric is placed in a mixture of two oil-in-water emulsions with opposite electrical charges. In preliminary tests to find the best negatively charged emulsion, a number of commercial anionic surface-active detergents were tested for their ability to form stable emulsions with technical white oil. 'Igopon T' formed the best emulsion with the minimum of frothing. Formulae are given for preparing a negative emulsion and a positive emulsion made with 'triton K-60' (Type A emulsions).

Type A

Negative emulsion:	
Oil ('Marcol HX')	200 g.
'Igopon T'	20 g.
Water (65° C.)	742 c.cm.
Positive emulsion:	
Oil	200 g.
'Triton K-60'	20 g.
Water	742 c.cm.

It is known that cotton when immersed in water becomes negatively charged. The finding that cotton sheeting would absorb oil faster from a positively charged emulsion than from one negatively charged was to be expected. However, effective oiling depends on the cotton fabric being placed in a mixture of two oppositely charged emulsions, the proportions of the two being accurately balanced so that natural coagulation occurs with complete exhaustion of oil in the treating bath. A balance test was devised to find the correct proportions. Stoppered tubes containing mixtures in various proportions were shaken and allowed to stand. Tubes containing ratios of negative to positive emulsions between 3 : 5 and 4·5 : 5 (optimum, 3·75 : 5) showed complete coagulation with separation into two layers, the lower being almost completely free of oil. Thus mixtures in these proportions should afford effective oiling; these results were confirmed by immersing cotton samples in mixtures of varying proportions and estimating the rate of which oil was adsorbed. Adsorption of oil was more rapid when the negative emulsion was added to the treating bath before the positive. The effect of *p*H was studied, but no advantage was found to result from its adjustment.

Formulae are given for another pair of emulsions, negatively and positively charged (Type B).

Type B

Negative emulsion:	
Oil	60%
'Igopon T'	1·32%
Water	38·68%
Positive emulsion:	
Oil	70%
'Triton K-60'	1·75%
Water	28·25%

These had a higher proportion of oil and a smaller amount of emulsifying agent; they were more nearly like those used for oiling blankets. Balance tests on the two pairs of emulsions were performed over a 2-month period. There was no evidence of instability. The optimum ratio for mixing the negative and positive emulsions was the same for both pairs, but the 'usable range' was smaller for Type B emulsions.

The oiling process was tested under laboratory conditions, using a launderometer. Assays of oil adsorbed on the fabric, deposited on the sides of the jar, and remaining in the bath were made when the fabric was both washed and oiled (with and without inclusion of a bleach) and when it was only oiled. About 80% of the total oil was deposited on the cotton, 2·5–5% remained in the bath, and 4–9% was deposited on the sides of the vessel. The oil content of the fabric was about 5%. The findings were not affected by preliminary laundering. A larger-scale trial was made using a commercial laundry wash wheel. Results were satisfactory. After 3 successive oilings there was no evidence of accumulation of oil in the fabric; after the laundering stage the fabric had only 1% of oil. There was considerable loss of oil by deposition on the wash wheel, so that it was necessary to calculate for 7% oiling in order to obtain 4–6%. The film of oil could be removed by washing the wheel with soap and alkali.

Satisfactory oiling was obtained with Type B emulsions, although a more careful balance was necessary. Whether this is possible in large-scale working can be determined only by practice. This pair of emulsions has the advantage that the positive emulsion is the same as that used for oiling blankets.

D. G. ff. Edward.

Study of Absenteeism during a Five-month Period. Following Influenza "A" and "B" Vaccination. NEWQUIST, M. N., and PAGE, R. C. (1946). *Industr. Med.*, **15**, 676.

An influenza epidemic in New York in December, 1945, was associated with type B virus. Mass vaccination of 665 office employees with A and B influenza vaccine was thereafter carried out and absenteeism recorded for 5 months. This group lost 673 days from work (1·01 days per employee). A control group of 656 employees lost 456 days (0·69 day per employee).

D. Stewart.

Sickness Absenteeism Among Industrial Workers, Third and Fourth Quarters of 1945. GAFAFER, W. M. (1946). *Publ. Hlth. Reps., Wash.*, **61**, 1,095.

Sick absence differs little (except in the method of recording) in the U.S.A. and in England. The incidence of absence (excluding industrial injuries and venereal diseases) lasting 8 days or longer per 1,000 males was 120 and 157 respectively in the third and fourth quarters of 1945. Since 1939 there has been a steady increase, until the 1945 rate is 70% up, the greatest increase (142%) being for diseases of the heart and arteries and for nephritis. Respiratory and digestive diseases together account for over half the absences.

T. A. Lloyd Davies.

Susceptibility to Colds. An Experimental Investigation Amongst Factory Workers. STOCK, J. P. P. (1946). *Brit. J. phys. Med.*, **9**, 145.

This investigation was carried out among employees of a Manchester factory in an experimental clinic for the treatment of common respiratory infections. The treatment adopted consisted chiefly of the application of argyrol (mild silver proteinate) and chloretone (chlorbutol), accompanied by short-wave diathermy. There was a close association between chronic catarrh of the upper respiratory tract and susceptibility to colds. The incidence of colds was significantly greater in those who had catarrh than in those who had no such symptoms. Patients treated for catarrh and responding had a lower incidence of colds than those who failed to benefit. The authors believe that chronic infection may predispose to colds or may be the result of previous colds.

A. J. Rhodes.

Weil's Disease: Occurrence among Workers in Welsh and Scottish Coal Mines. JENKINS, T. H., and SHARP, W. C. (1946). *Brit. med. J.*, **1**, 714.

Since April, 1940, Weil's disease, or spirochaetosis icterohaemorrhagica, has been a scheduled disease, but as it usually occurs through the medium of infected water in many places, such as mines, sewers, fish-cleaning premises, piggeries, farm middens, and slaughter-houses, no process was included in the Order. The sufferer must prove that the disease was contracted through his work. The disease has been notifiable in Scotland since 1924, and an average of 38 cases a year (not necessarily in miners) have occurred since that date. Since 1933, 11 fatal and 36 non-fatal cases have been reported from South Wales. The authors review 34 fatal and 64 non-fatal cases (occurring in 17 Scottish and Welsh mines); all the mines concerned are drifts or slants (or connected with slants), and each mine was known to be infected with rats at the time of occurrence of the disease. The workings were wet, and pools of water frequent. All the Welsh mines, and the two Scottish mines with the highest incidence, employed horses or ponies underground. All cases were underground workers, except one in a surface worker who may have paid visits inbye. The regulations under the Coal Mines Act in effect require that horse-feed and water should be taken inbye. Spillage is common. Cuts and abrasions are frequent in all underground workers.

The main carrier of Leptospira is the sewer rat (*R. norvegicus*), and far less commonly the black rat (*R. rattus*). The average life of a rat is two years, and a pair of rats may produce 600 or more progeny in a year. Rats gain access to mines through slants or via horse-feed. Horse-feed and scraps of bread are the main food of rats. Rats also feed on human and horse excreta. In mines where rats entered through shafts they soon died out when horses were replaced by mechanical haulage. Preventive measures are: (1) extermination of rats; (2) prevention of reinfestation; (3) rendering food inaccessible to rats: (a) horse-feed should be properly stored in steel bins, (b) workmen should carry all food in metal tins and desist from throwing away scraps, (c) full use should be made of chemical sanitary conveniences (d) there should be restriction of horse-feeding points and proper disposal of horse excreta; (4) drainage of the pools, etc., and chemical treatment of stagnant pools; (5) protective clothing (especially gum-boots), (6) first aid for all injuries; (7) pit-head baths (and, if feasible, washing of hands before eating). Facilities for laboratory diagnosis and hospital treatment are available in the Scottish and South Wales coal-fields.

T. A. Lloyd Davies.

Industrial Management and Occupational Cancer. HUEPER, W. C. (1946). *J. Amer. Med. Ass.*, **131**, 738.

Proof of the carcinogenetic properties of a number of important substances and physical agents in common use in industrial processes has been obtained by reproducing the same tumours in animals. Nevertheless there are still many human occupational cancers of unknown ætiology. These are likely to appear after 5–15 years' exposure. After enumerating the pathological conditions which may accompany certain trades, a plea is made for industry to devote more effort to the study of occupational cancer, especially of its cause, prevention, and control. Several points are listed as a basis from which to wage an attack. Among these are the safety construction of buildings and plant to eliminate poisonous substances in manufacture, leak-proof packing and storage, the full protection of personnel, adequate medical supervision and follow-up, the compulsory notification of cancerous and precancerous industrial diseases, compensation, regular government inspection of factories, and the formation of a consultative committee well versed in the scope of industrial cancer.

J. L. Lovibond.

Medicine in the Mines. (Au sujet de la médecine des mines.) CHENET, S. (1946). *Méd. français, Paris*, **6**, 294.

Personality Components in Employment Problems. CLARKE, E. K., and LAW, S. G. (1946). *Occup. Med.*, **2**, 116.

Medical and Welfare Services for Indian Coal-Miners. EDITORIAL (1946). *Prescriber*, **40**, 164.

Occupational Medicine—Retrospect and Prospect. NEWQUIST, M. N. (1946). *Industr. Med.*, **15**, 509.

The Safety Engineering Unit. (1946). *Industr. Med.*, **15**, 514.

The Worker and his Job: Symposium. KESSLER, H. K., BOWMAN, K. M., GRISELLI, E. G., DURAND, W. F., SHEPARD, W. P., LEGGE, R. T., BAHRS, G. O., ENNIS, G. E., HICKER, H. B., QUINN, F. B., HUNTER, F. W., and PRICE, O. W. (1946). *Industr. Med.*, **15**, 515.

Psychology Applied to Industry. (La psicologia applicata al lavoro industriale.) CARLO, T. (1946). *Med. internaz., Milano*, **54**, 83.

PROCEEDINGS OF THE ASSOCIATION OF INDUSTRIAL MEDICAL OFFICERS

ANNUAL GENERAL MEETING

The Annual General Meeting, 1946, of the Association of Industrial Medical Officers was held on Friday, Oct. 18, 1946, at the London School of Hygiene and Tropical Medicine, Dr. W. Blood being in the chair. The Minutes of the previous meeting were read, confirmed, and signed.

Agreement with the British Medical Association

The Chairman announced that the delegates appointed by the Association had reached the following agreement (subject to ratification by the meeting) with the British Medical Association :

1.—If the Association of Industrial Medical Officers desires to urge upon central or local authorities, or other similar bodies, any medico-political policy affecting the interest of public or private practice, or is consulted thereon by such authorities or bodies, it shall communicate its proposals to the British Medical Association before taking action.

2.—If such policy or proposals are approved by the British Medical Association either in their original form or in an agreed amended form, all action consequent thereon will be taken by the British Medical Association, and the Association of Industrial Medical Officers will refrain from taking any further action.

3.—If the proposals of the Association of Industrial Medical Officers are not approved by the Council of the British Medical Association, or if the former Association is dissatisfied with the form in which the Council of the British Medical Association is willing to take action thereon, the Association of Industrial Medical Officers shall be free to take action independently.

4.—The British Medical Association will provide for the representation of the Association of Industrial Medical Officers on its Industrial Medicine Committee, and the Association of Industrial Medical Officers will provide for the representation of the British Medical Association at its meetings.

After discussion, the agreement was ratified by a majority, three dissentient votes being recorded.

Election of Members to serve on the Industrial Medicine Committee of the B.M.A.

The following members were elected to represent the Association on the Industrial Medicine Committee of the British Medical Association : the Chairman (ex-officio), the Hon. Secretary (ex-officio), Dr. A. J. Amor (London), Dr. M. W. Goldblatt (Manchester).

Hon. Treasurer's Report, 1945–46

The Hon. Treasurer presented the Statement of Accounts, 1946, which was adopted. The financial affairs of the Association continued to be on a sound footing. The position as regards members serving in His Majesty's Forces was not clear, but the matter was being sifted out.

The Hon. Treasurer read out the names of 9 Ordinary and 2 Associate Members whose membership had lapsed under Rule 7 of the Constitution.

Election of Members

Seventeen new Ordinary, and 6 new Associate Members were elected. Two Ordinary Members were elected to Associate Membership.

Election of Officers, 1946–47

The following were elected to serve the Association in the offices stated for the year 1946–47 : Hon. Secretary, Dr. P. Pringle (London) ; Hon. Treasurer, Dr. Patricia Shaw (Nottingham) ; Executive Committee, Drs. J. G. Billington (Birmingham), G. R. Hargreaves, A. Meiklejohn (Glasgow), J. A. A. Mekelburg (London), and C. L. Potts (Birmingham).

Messrs. Ogden, Hibberd, Bull, and Langton were elected as auditors.

Venereal Diseases Photographic Exhibition

The Venereal Diseases Photographic Exhibition prepared by the Ministry of Health was placed before the meeting.

British Council for Rehabilitation

Dr. J. Craw (Whitehaven) and Dr. W. Gunn were appointed to represent the Association on the British Council for Rehabilitation.

Public Business

Following the meeting, a dinner was held at the London School of Hygiene and Tropical Medicine. Dr. E. G. Rawlinson, Mr. B. Hanman, and Dr. D. Hunter accepted invitations as guests of the Association.

On Oct. 19, Dr. D. Hunter and Dr. R. S. F. Schilling described a visit to the United States. Dr. Schilling said that their object was to find out more about the activities of the United States in the research and practice of industrial medicine and hygiene, and to establish a closer contact between the two countries. Visits were made to many plants, to the Federal State Divisions of Industrial Hygiene and Labor, and to research institutions and hospitals. Their work was briefly described, and Dr. Schilling said that the lessons to be learnt from this visit could be summarized as follows :

The services in the large plants in the United States appeared to be more efficient and better equipped than those in Great Britain, where the engineer and chemist had less opportunity of playing their part in the prevention of accident and disease. As in Great Britain, no comprehensive service was provided for the small plants except in a few instances, such as the invaluable experiment in Long Island City where various Government Departments had collaborated to provide a service for the small factories in this area. Conditions in the smaller factories were probably better controlled in Great Britain through the Factories Act, 1937, and through Regulations which were more comprehensive and more rigidly enforced than the U.S. health safety codes. Much more money was spent per workman in the United States by private industry and Government Departments on industrial health research. Such expenditure was regarded as a good investment, as it saved losses from human inefficiency.

Dr. Donald Hunter showed a cinematograph film of the trip, from New York to San Francisco and back again to Boston.

NOTTINGHAM GROUP

A meeting of the Nottingham Group of the Association of Industrial Medical Officers was held at the Black Boy Hotel, at 7 p.m., on Dec. 12, 1946. Dr. Keatinge was in the chair and 16 members were present. A discussion was opened by Mr. K. D. Downham, B.V.Sc., M.R.C.V.S., D.V.H., and Mr. G. J. Christie, M.R.C.V.S., on "Animal Diseases Communicable to Man." Mr. Downham dealt particularly with generalized and local infections and swine erysipelas in man, and Mr. Christie with measures needed to protect milk from tuberculous infection. Mr. Downham referred to epidemics of arthritis occurring in young pigs from which no organism had been isolated, but in which the farmer owning the herd had also suffered from arthritis. The possibility of a "rheumatoid" type of arthritis occurring after a swine erysipelas infection was discussed. The striking fact about *B. rhusiopathial* was that it affected sheep, birds, pigs, chickens, and fish. Accordingly the occupational incidence of infections in the human was correspondingly wider, varying from slaughterman, fisherman, butcher, and housewife. In all it was related to the handling of food.

Mr. Christie's paper led to a discussion on whether the desirability of pasteurization of milk or B.C.G. vaccine was to be preferred as a method of eliminating bovine tuberculosis in chicken. No justification could be deduced for "salting" with live organisms, but to prevent catastrophies pasteurization must be effective.

Mr. Crooks, Dr. Ferguson, and Dr. Whimster stressed the change taking place in the biological habits of organisms because of new hygienic arrangements or methods of treatment, so that the natural habitat became uncomfortable. In particular, the decrease in the number of cases of pneumococcal pneumonia at the Nottingham General Hospital was probably due to the eradication of pneumococcus by penicillin. There was a corresponding rise in the incidence of atypical pneumonia not responding to penicillin. Mr. Downham referred to the difficulty experienced in Africa in re-infecting game that had previously harboured trypanosomes, and from which sanitary measures had eradicated the organism, thus forcing it to adopt different biological habits.

SCOTTISH GROUP

A meeting of the Scottish Group of the Association of Industrial Medical Officers was held at the Department of Industrial Health, University of Glasgow, on Dec. 11, 1946, when Dr. Rogan gave a talk on the Austin Motor Company's rehabilitation shop. He traced the early history of the rehabilitation shop, and said that its establishment enabled an employee of the Company to continue in gainful employment from the time when he sustained an accident until he was resettled in his pre-accident job or in some other suitable occupation. He indicated the necessity for adequate medical and surgical supervision during the period of rehabilitation, and outlined the scheme under which the surgeons of the Birmingham Accident Hospital attended weekly at the Rehabilitation Shop to advise on and direct the rehabilitation process. He discussed the problem of medical rehabilitation and suggested that facilities for medical rehabilitation were just as necessary as those for surgical rehabilitation, and that the individual disabled by a medical condition was usually much worse off than his surgical counterpart, in that he was ineligible for compensation. The Austin experiment had passed from the experimental stage, and had now become an established part of the Company's policy.

Dr. Rogan discussed the application of the principles embodied in the Austin Rehabilitation Shop to the working population in general. There was no reason why large firms should not emulate the Austin project, modifying it suitably to their own particular requirements. Unfortunately the large employers of labour in this country employed only a small proportion of the total labour force. Dr. Rogan thought it might be possible for smaller firms to group together and to support rehabilitation shops organized in general conformity with the Austin Rehabilitation Shop, but with this difference: that it might be desirable for them to manufacture one specific article, otherwise the economic difficulties of assuring a smooth, even flow of materials through such workshops might prove insurmountable. Planning the sites of such workshops would require careful consideration; it might be advisable to locate them in industrial areas, and thus near the workers' homes or near general hospitals. Employment of the workers could thus logically succeed and in many cases supplant occupational therapy, which in its present form is often grossly uneconomic from the workers' point of view.

Industrial Health and Social Medicine

Prof. Thomas Ferguson spoke on industrial health as an integral part of social medicine. He said it was neither easy nor desirable to draw a line between industrial health and other aspects of social medicine. Even if it were accepted as the primary aim of the industrial health service to safeguard and promote the health of workers while at work, it was nevertheless certain that their health, like their working efficiency, was profoundly influenced by factors, such as housing or domestiic affairs, that had little factory association. It was equally true that factors arising in the workshop influenced the health and happiness of the individual worker and sometimes his family.

Most sickness responsible for incapacity for work was sickness of the community as a whole—diseases not specific to industry, though work and working conditions might aggravate them and sometimes promote their spread. Except for silicosis and dermatitis, toxic factors were of minor significance in the total ill-health among industrial workers, and, given reasonable standards of working environment, they should continue to become still less important.

Injuries and respiratory diseases raised the standardized mortality rate of miners, which was higher than that of employed males generally. But the mortality of miners' wives was even less favourable, and it was reasonable to assume that, while the circumstances of underground employment contributed to the mortality of miners, the whole life of the miner and his family had an unfavourable influence on health. The Miners' Welfare Commission early came to the conclusion that, while it must seek to improve underground and pithead conditions, it ought also to try to improve the amenity of the mining villages. The work of the Commission was a contribution to social medicine of which the importance was not yet fully realized.

Prof. Ferguson was particularly struck with the preponderance of industrial factors operating in the cases seen by him as Consultant in Social Medicine to Falkirk Royal Infirmary. Physicians and surgeons were coming to realize that the interest of the patient demanded more than the practise of their art in the traditional sense, and this outlook should be fostered. The industrial health service had developed as a thing apart from the health

services as a whole. Ten years ago, however, the Report of the Committee on Scottish Health Service recognized that success or failure in either service had a direct bearing on the other, and the Committee felt that industrial health should be treated not as an isolated entity, but as an essential and integral part of national health policy. The Committee recommended that there should be closer liaison arrangements for the pooling of knowledge and for joint action on common problems, and that, for instance, the opportunities presented by the medical examination of young entrants into industry should be more fully utilized. It was true that much had been done during the past ten years to place the examination of young entrants to industry on a better footing, and the extension of school age, with statutory requirements that young people should continue part-time post-elementary education, offered scope for the extension of health supervision of young industrial workers. Quite likely these young people would be subject to school medical examination up to the age of 18, and at least four medical agencies would be interested in many of them—the school doctor, the industrial medical officer, the examining surgeon, and the family doctor. It was clearly important to secure an enlightened integration of effort and to secure the development of vocational guidance necessary to diminish the prevalent wastage of manpower and the dead-ending that got so many youngsters away to a bad start in life.

The Disabled Persons (Employment) Act, good as were its intentions, had raised many awkward administrative issues. It was already clear that many of the most difficult problems in resettlement were concerned with medical rather than surgical disabilities, and that nearly all were connected with social problems. Prof. Ferguson felt that soon there must be a co-ordinated approach to the study of the health and industrial problems raised by cardiac disease, tuberculosis, and degenerative conditions generally.

Sooner or later it would become necessary to review the position of the industrial medical officer. Ought he to have any statutory authority? What should be his relation to the State Departments, to the new hospital system, to the new health centres, and to the new general practitioner? The scope of occupational medicine should be wide, including applied physiology, based on the recognition that for most folk congenial work under reasonable conditions is one of the best prescriptions for healthy living.

The Regulations for the Diploma in Industrial Health of the Royal College of Physicians demanded attendance at an introductory course in social medicine corresponding to the first three months of the new D.P.H. Course. The preliminary course was concerned with such things as the history of public health and public assistance; the existing functions of central and local health authorities and the structure of health services; the health problems of certain groups of the population; hospital services and resettlement; social security and the agencies for the relief of poverty and promotion of social welfare; the elements of social economics; the nature, sources and control of infections; environmental factors in relation to health; criteria of national well-being and the influence of social conditions on vital statistics; methods of health education, social surveys, and social case records; and the preparation of memoranda bearing on various aspects of the health of the people. Prof. Ferguson asked his listeners whether teaching along these lines was, in their opinion, likely to be of value to the industrial medical officer. Could they suggest any other broad subject-group that ought to be included, bearing in mind that the second six months of the course made provision for more detailed study of specific technical subjects? The aim in an introductory course of the type outlined must necessarily be to provide, on as broad a basis as possible, not only a working knowledge of existing social services, but also a cultural background against which more technical problems could be considered.

Then there was the question of research. Prof. Ferguson was sure that not nearly enough thought had been given to the impact of social factors on industrial health. Some work had been done, much of it under the auspices of the Industrial Health Research Board, on the relationship between social factors and output—nutritional factors, travelling time, sleep in relation to working shifts, etc. And, following the 1931 census, the Registrar-General had studied the death-rates prevailing among different social classes of the population. But there were many problems about which we knew little. Why did people take up certain kinds of employment? How far was occupational drift influenced or compelled by social considerations? How could we place successfully in industry the high-grade defective who, as war experience showed, was capable of useful physical or repetitive work? Could we not do more to help young people entering industry? Prof. Ferguson said it was hoped soon to begin a survey of the experience of young people leaving Glasgow schools at the age of 14. The survey, starting from the child's school record, would follow his experience over a period of four or five years and would take special cognisance of his difficulties—physical, economic, and in relation to work.

Dr. Meiklejohn concluded the symposium and the following were among the more important topics on which he commented:

1.—The present position and strength of medicine in industry as represented by full-time and part-time medical and nursing services. "No nurse should be employed in industry except under medical direction and supervision."

2.—The future "Health Service" in industry.

3.—Great Britain a country of small factories, many of them "slums." Part-time M.O.s should be part of an *integrated service* directed by specialist industrial M.O.s

4.—The doctor-patient relationship in industry.

5.—A plea for a balanced objective judgment in the application of "new discoveries," e.g. mass radiography.

CORRECTION

On p. 76 of the January issue in the Proceedings of the Association of Industrial Medical Officers, Scottish Group, the name of Dr. J. M. Rogan was wrongly printed as A. S. Rogen.